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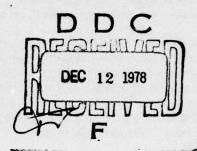
INTERACTIONAL AERODYNAMICS OF THE SINGLE ROTOR HELICOPTER CONFIGURATION

VOLUME VIII-B - Frequency Analyses of Wake Single Film

Data, Basic Configuration Wake Exploration

Philip F. Sheridan

Boeing Vertol Company P.O. Box 16858 Philadelphia, Pa. 19142



September 1978

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Prepared for

APPLIED TECHNOLOGY LABORATORY

U. S. ARMY RESEARCH AND TECHNOLOGY LABORATORIES (AVRADCOM)

Fort Eustis, Va. 23604

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#### APPLIED TECHNOLOGY LABORATORY POSITION STATEMENT

In 1975 a wind tunnel test program was conducted in the Boeing-Vertol 20-foot V/STOL Wind Tunnel on a 1/5th-scale UTTAS model to investigate and find solutions for several aerodynamic problems encountered during the UTTAS flight-testing. Specifically, these tests focused upon (a) the structure of the hub/rotor wake in the vicinity of the empennage, (b) the formulation of the ground vortex and its relation to hub loads and fuselage loads during transition, and (c) the occurrence of vibratory air pressures from the blade passing over the fuselage. Only portions of the above-mentioned wind tunnel test data were reduced and analyzed in addressing the flight-test problems of the UTTAS aircraft.

Under Contract DAAJ02-77-C-0020, Boeing-Vertol completed analyses on the data to understand more completely the aerodynamic interactions that are involved and to formulate instructions for the guidance of designers in these respects. The results of these studies are applicable to all existing and future single-rotor/tail rotor helicopters. The data have been segregated according to aerodynamic interactions and associated phenomena/problem areas. From this body of knowledge, a generalized set of design guidelines meaningful to the single-rotor helicopter design concept formulation were developed and are included in these reports.

Mr. Robert P. Smith of the Aeronautical Technology Division, Aeromechanics Technical Area, served as project engineer for this effort.

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Frequency Spectrum	Configuration	rowered model
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spectrographs of t	of the three volumes of Volum he model helicopter hub/rotor	wake velocities derived from
the single-film ve	locity transducer data. This	sub-volume deals with the
wake characteristi	cs of the baseline configurati	fons.
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#### PREFACE

The entire report describing the investigation of INTERACTIONAL AERODYNAMICS OF THE SINGLE-ROTOR HELICOPTER CONFIGURATION comprises eight numbered volumes bound as 33 separate documents. The complete list of these documents is as follows:

#### Volume I, Final Report

#### Volume II, Harmonic Analyses of Airframe Surface Pressure Data

- A Runs 7-14, Forward Section
- B Runs 7-14, Mid Section
- C Runs 7-14, Aft Section
- D Runs 15-22, Forward Section
- E Runs 15-22, Mid Section
- F Runs 15-22, Aft Section
- G Runs 23-33, Forward Section
- H Runs 23-33, Mid Section
- I Runs 23-33, Aft Section

#### Volume III, Flow Angle and Velocity Wake Profiles in Low-Frequency Band

- A Basic Investigations and Hubcap Variations
- B Air Ejector Systems and Other Devices

# Volume IV, One-Third Octave Band Spectrograms of Wake Split-Film Data

- A Buildup to Baseline
- B Basic Configuration Wake Explorations
- C Solid Hubcaps
- D Open Hubcaps
- E Air Ejectors
- F Air Ejectors With Hubcaps; Wings
- G Fairings and Surface Devices

#### Volume V, Harmonic Analyses of Hub Wake

#### Volume VI, One-Third Octave Band Spectrograms of Wake Single Film Data

- A Buildup to Baseline
- B Basic Configuration Wake Exploration
- C Hubcaps and Air Ejectors

#### Volume VII, Frequency Analyses of Wake Split-Film Data

- A Buildup to Baseline
- B Basic Configuration Wake Explorations
- C Solid Hubcaps

D - Open Hubcaps

E - Air Ejectors

F - Air Ejectors With Hubcaps; Wings

G - Fairings and Surface Devices

Volume VIII, Frequency Analyses of Wake Single Film Data

A - Buildup to Baseline

B - Basic Configuration Wake Exploration

C - Hubcaps and Air Ejectors



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#### INTRODUCTION

Volume VIII is similar in its format to Volume VII, presenting machine plotted spectrograms. Here the velocity data from the single film outboard transducers is considered in contrast to the split film data of Volume VII which gave flow angle information as well as velocity. The data analysis here was conducted for a limited number of test runs as it is of secondary interest. The runs are the same as for the harmonic analysis of Volume V.

The sub-volumes of Volume VIII display data derived from the following test runs:

Volume VIII-A - 149, 150, 160, 156, 158, 159 Volume VIII-B - 111 -119, 121, 135, 136 Volume VIII-C - 188, 211, 168, 167, 194, 161, 154, 172, 174, 176, 203, 205, 197

These runs follow the order of the logical arrangement of the Outline of Wake Investigations, Table 1, from which they have been selected. The Table I outline and other material is included for reference and as context to the work of each sub-volume. Table 2, the List of Test Runs, arranges the runs in numerical order and gives pertinent text parameters.

The Index of Rake Positions, Table 3, lists the hot film transducer rake positions in the model coordinate system for each run and its test points. The main feature of Table 3 is the indexing of the test point number to the model water line station and butt line as it varied from run to run. The table groups the runs as they shared the indexing correspondence of point with position. It is emphasized that the runs in a group do not necessarily all share the same number of test points but they do have same correspondence within their respective ranges of test points.

The orientation of rake is shown pictorially in Figures 1 through 6 for the various test runs. Figure 7 presents a scaled drawing of the model with reference to the three-axis coordinate system.

TABLE 1 OUTLINE OF WAKE IN			
Description	Configuration Code	The state of the s	Base- line
Build-up to Baseline	(Sept 1, 700) (1, 85)	1 1344	30 3388
1. Nacelles removed	K <sub>13</sub> +H <sub>1</sub> -N	149	150
2. Blades off, rotating hub	K <sub>13</sub> -M+H <sub>1.0</sub>	160	156
3. " , non-rotating hub	K <sub>13</sub> -M+H <sub>1.0</sub>	158	156
4. " , hub off	K <sub>13</sub> -M-H <sub>1.0</sub>	159	156
Basic Configuration	Control Acoustic to		
1. Wake Explorations near Empennage			
(a) 15" Long. + traverse at T/R C.L.	K <sub>1</sub>	111	
		112	
(b) 9" Vert. + " above T/R " (c) 2" " in vortex	•	1113	
(d) 8" " (continue 112)		1114	
(e) 13" " behind stab.		115	
(f) Lateral traverse, left stab.	The state of the s	116	
(One T.P. only)		1-10	
(g) Same continued	•	117	
(h) Same continued (One T.P. only)	The same with the same	118	
(i) Lateral traverse right stab.		119	
(j) T/R effect on wake	$K_{11} + T_2^0$	121	115
2. Climb/Descent Studies	Spin Tally Lameth		0
(a) Climb 900 FPM	V	135	
(b) Descent 800 FPM	K <sub>1 1</sub>	136	
Effect Of Hub Caps	10		
1. Solid Caps on Canister	rid rid		91
(a) 7.6" diam. 2.17" ht. soft Pitch Arms	K <sub>11</sub> -H <sub>1.0</sub> +H <sub>1.2</sub>	137	136
(b) 7.6" diam. 2.17" ht. stiff Pitch Arms	K <sub>13</sub> +H <sub>1.2</sub>	153	156
(b) 7.6" diam. 2.45" ht. flt. test config.	K <sub>13</sub> +H <sub>1.2.1</sub> +I <sub>1</sub> +E <sub>1.0</sub>	207	188

## TABLE 1 (CONTINUED)

### OUTLINE OF WAKE INVESTIGATIONS

Description	Configuration Code*	Run No.	Base- line
Effect of Hub Caps (Continued)	<u>and Lo</u> pes	132.	pre ESS u
2. Solid Caps Raised Above Canister	hoveless	851	sonia .
(a) 7.6" diam. 2.45" ht. 70" depth, .55 gap	H <sub>1.2.2</sub> +I <sub>1</sub> +E <sub>1.0</sub>	208	188
(b) 10.0" diam. 3.25" ht. 1.55" depth, .50" gap	H <sub>1.8.1</sub> +I <sub>1</sub> +E <sub>1.0</sub>	189	188
(c) 10.0" diam. 4.125" ht. 2.05" depth, .875" gap	H <sub>1.8.2</sub> +I <sub>1</sub> +E <sub>1.0</sub>	190	188
(d) Repeat of 189	11 11 11	210	188
3. Open Caps Without Underbody	801003		12.12.5
(a) 10.0" diam. 1.25" gap,blades (b) " " gap, no blades	H <sub>1.0.1</sub> -H <sub>1.0.1</sub> +E <sub>1.0</sub>	193 166	188/166 158
(c) " 2.05" gap, blades	H <sub>1.14.1</sub> +I <sub>1</sub> +E <sub>1.0</sub> H <sub>1.0.1</sub> -M	211 165	188 158
(e) " " 1.87" gap, blades	H <sub>1.0.3</sub> +I <sub>1</sub> +E <sub>1.0</sub> H <sub>1.7.1</sub> -M	191 168 167	188 156/16: 158
	H <sub>1.7.2</sub>	169	156
4. Open Caps with Underbody	office to the	1397	7.40
	H <sub>1.11.1</sub> +I <sub>2</sub> +E <sub>1.0</sub> H <sub>1.11.1</sub> +I <sub>2</sub> +E <sub>4.0</sub> H <sub>1.11.2</sub> +I <sub>2</sub>	194 198 202	188 188 194
	H <sub>1.5.1</sub> -M	164	158
	H <sub>1.5.2</sub> -M	161	158
	H <sub>1.5.4</sub> -M	163	158
(g) " " 4.0" gap, no blades	H <sub>1.5.3</sub> -M	162	158
	H <sub>1.5.2</sub>	154	156/16

### TABLE 1 (CONTINUED)

### OUTLINE OF WAKE INVESTIGATIONS

Description	Configuration Code*	Run No.	Base- line
5. Miscellaneous Hub Covers  (a) Hub fairing 16" diam. (b) Wham-O-Frisbee 10" diam. (c) Fab. glass Frisbee 16" diam.	H <sub>1.3</sub> H <sub>1.9.0</sub> +E <sub>1.2</sub> H <sub>1.9.1</sub> +E <sub>1.2</sub>	151 182 183	150 181 181
Effect of Air Ejectors	ne i jest ikke il G skladu Apatulei		2 143 2 143
o. Witte 130 psi	H <sub>1.0</sub> +E <sub>1.0</sub> H <sub>1.0</sub> +E <sub>2.5.1</sub> H <sub>1.0</sub> +E <sub>3.5.2</sub> H <sub>1.0</sub> +E <sub>3.5.4</sub>	174 175 176 184 187 203	156 156/172 156/173 156/174 156/173 156/174 156 156/203 156/203
Air Ejectors with Open Hub Caps with Underbodies			
1. 7.6" diam. 1.25" gap, 0 psi 2. " " " 20 psi 3. " " " 40 psi 4. " " " 150 psi	H <sub>1.11.1</sub> +l <sub>2</sub> +E <sub>1.0</sub> """ H <sub>1.11.1</sub> +I <sub>2</sub> +E <sub>4.0</sub> """ H <sub>1.11.2</sub> +I <sub>2</sub> +E <sub>4.6</sub> H <sub>1.5.4</sub> +E <sub>2.5.1</sub>	195 196 197 198 199 200 201	188/172 188 188/173 188/174 188/194 188/196 188/196 188/200 156/176
Effect of Wings and Misc.			
1. Wings (a) Nacelle-mounted stub wing (b) Single slotted flapped wing (c) Dougle slotted flapped wing (d) Boom-mounted stub wing	H <sub>1.0</sub> +W <sub>1.0</sub> +E <sub>1.1</sub> H <sub>1.0</sub> +W <sub>3.0</sub> +E <sub>1.0</sub> H <sub>1.0</sub> +W <sub>2.0</sub> +E <sub>1.0</sub> H <sub>1.0</sub> +W <sub>4.0</sub>	178 180 179 186	181 181 181 156

TABLE 1 (CONTINUED)

#### OUTLINE OF WAKE INVESTIGATIONS

	Des	cription	Configuration Code*	Run No.	Base- line
2.	(b) Round (c) Exten (d) Flat (e) Forwa Surface D (a) Vorte	top behind shaft top behind shaft ded flat top fairing top + 16" cap, 4" gap rd fairing/nacelle fairing	K <sub>1</sub> 1+D <sub>1</sub> K <sub>1</sub> 1+D <sub>2</sub> H <sub>1</sub> +D <sub>4</sub> H <sub>1</sub> · 7 · 2+D <sub>4</sub> P <sub>1</sub> · 0 K <sub>1</sub> 1+VG <sub>2</sub> · 1 K <sub>1</sub> 1+FV <sub>1</sub>	140 141 170 171 152	138 138 156 170 156
	(c) Longi	tudinal strakes orosity spoiler	H <sub>1·5·3</sub> +S <sub>4</sub> K <sub>11</sub> +X <sub>1</sub>	155	156 138
			189 0 200 199 50 199 601 "		
			D des requires to an early		
			20		
			000		
			Contract point		
			THE PART OF STREET	6	
			Evrodyn'i Sondolin Dringell Sondolin		

<sup>\*</sup>Basic Code is K13 unless noted otherwise.

	WAKE
	HUB
RUNS	THE
	OF
TEST	SNO
OF	TI
2. LIST	INVESTIGATIONS
2.	NV
TABLE	BASIC I

TAIL	ROTOR	Off				•	=			=	On	Off	
MR HT.	h/d	8				=	=	=		=	=	=	=
MODEL	•	-2.0		=	=	=	=			:	=	4.5	-2.0
MODEL	<b>9</b> 8	0.9					=			=	=	0.9-	0.9
DISK	LDG.	8				2	=					u	
RPM	MR/TR	1433/0	=	=	=	2					1433/ 4500	ш	
Vrun	KNOTS	80	=	=		2	=	=			=	=	
MOTHET CHOOM MOTHER COMPANY	CONFIGURATION/ CONDITION	K <sub>11</sub> /15" Long. wake traverse at TR center line	" /9" Vert. wake traverse above TR center line	" /2" Vert traverse through MR vortex	" /8" Vert. traverse below TR center line	" /13" Vert. traverse behind stabilizer	" /Lateral traverse - left stabilizer	" /116 continued	" /116 continued	" /Lateral traverse - right stabilizer	K <sub>11</sub> +T <sub>2</sub> /Effect of tail rotor flow on wake	$K_{11}/W$ ake in 900 fpm climb	" /Wake in 800 fpm descent
RUN	NO.	111	112	113	114	115	116	117	118	119	121	135	136

TABLE 2 (CONTINUED) LIST OF TEST RUNS
EVALUATION OF WAKE-ALTERING DEVICES

LDG, a° ψ° h/d ROTOR  8 6 -3.8 ∞ Off  " " " " " " " " " " " " " " " " " "	RPM DISK
8 = = = = = = = = = = = = = = = = = = =	œ
	1433/0 8
: :	
:	
4.5 " " "	1075/0 4.5
	100 H
365 E S DH	=
	1433/0 8
:	

TAIL ROTOR Off = = = = = = = = = = MR. HT. 8 = = = = = -3.8 • ANGLES = = = = = = = MODEL 9 = = = = = = = = 2 DISK LDG. œ = = = = = = = = EVALUATION OF WAKE-ALTERING DEVICES MR/TR 1433/0 1433/0 RPM 0/0 0/0 = = = = TABLE 2 (CONTINUED) LIST OF TEST RUNS KNOTS VTUN 80 = = = = = = = K<sub>13</sub>-M+H<sub>1.0</sub>/Same as 158 except hub is K<sub>13</sub>-M+H<sub>1.0</sub>/Wake studies with blades off, hub not rotating K<sub>13</sub>-M-H<sub>1.0</sub>/Wake studies with hub of 10" open hub cap, no underbody, same cap vert. position as Run 154 strakes on aft crown K<sub>13</sub>-M+H<sub>1.5.2</sub>/Repeat of 154 without blades 4 " 5 K13-M+H1.0.2/Same as 165 with cap K13+H1.5.2+S4/Same as 154 except Kl3+H1.0/Baseline with Kl3,i.e., as 161 except K<sub>13</sub>-M+H<sub>1.5.3</sub>/Same as 161 except K<sub>13</sub>+H<sub>1.5.2</sub>/10" open hub cap, 7" underbody, 1.25"gap K<sub>13</sub>-M+H<sub>1,5,1</sub>/Same as 161 except 0.5" gap CONFIGURATION/CONDITION lowered by 0.5" stiff pitch arms rotating K13-M+H1.5.4/Same gap K13-M+H1.0.1/ 155 154 156 158 160 159 162 163 191 164 165 166 NO.

TABLE 2 (CONTINUED) LIST OF TEST RUNS EVALUATION OF WAKE-ALTERING DEVICES		CES
TABLE 2 (CONTINUED) LIST OF TEST RUI EVALUATION OF WAKE-ALTERIN	SN	G DEVI
TABLE 2 (CONTINUED) LIST OF TEST EVALUATION OF WAKE-ALTE	RU	RIN
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TABLE 2 (CONTINUED) EVALUATION	LIST	OF W
TABLE 2		EVALUATION
TABLE	7	-
	TABLE	

RUN	CONFIGURATION/CONDITION	VTUN	RPM	DISK	MODEL	MODEL	MR.	TAIL
NO.	TO HOSSIA SELECTION OF THE STREET	KNOTS	MR/TR	psf.	• 8	•	h/d	ROTOR
167	Kl3-M+Hl,7,1/16" open cap, no underbody, 2" gap	. 80	0/0	8	9	-3.8	8	Off
168	K <sub>13</sub> +H <sub>1,7,1</sub> /Blades on, same cap config. as 167		1433/0		•	•	•	•
169	Kl3+Hl.7.2/16" open cap, no under- body, 4" gap	п	0.115			=	•	•
170	K <sub>13</sub> +H <sub>1.0</sub> +D <sub>4.0</sub> /Extended flat top fairing on aft crown	и	11	u		•		
171	K <sub>13</sub> +H <sub>1,7,2</sub> +D <sub>4,0</sub> /Same fairing as 170 same cap as 169					•	=	•
172	Kl3+H1.0+E1.0(Opsi)/Basic air ejector zero blowing baseline				•	•	=	
173	$^{\mathrm{K}_{13}}$ $^{+\mathrm{H}_{1.0}}$ $^{+\mathrm{E}_{1.0}}$ $^{(40\ \mathrm{psi})/\mathrm{Same}}$ as 172 with 40 psi supply				=	•	=	
174	K <sub>13</sub> +H <sub>1.0</sub> +E <sub>1.0</sub> (150 psi)/Same as 172 with 150 psi supply	•				es •	=	•
175	(40 psi)/Ejector w ishroud at 40 psi		•	•	•	•	=	• 3
176	(150 psi  th 150 p							•
177	K <sub>13</sub> +H <sub>1</sub> .5 <sub>1</sub> 4+E <sub>2</sub> 5, 1(150 psi)/Same as 1/6 with 10" cap like 163	=				=		
178	K <sub>13</sub> +H <sub>1.0</sub> +W <sub>1.0</sub> +E <sub>1.1</sub> (0 psi)/Nacelle mounted wing	=	•	-	=		=	

ROTOR Off TAIL = = = = = = = MR. = = = = = -3.8 ANGLES = = = = MODEL = 9 2 = = = = DISK LDG. psf œ à = = = = = = = EVALUATION OF WAKE-ALTERING DEVICES RPM MR/TR 1433/0 = = = = = = = = TABLE 2 (CONTINUED) LIST OF TEST RUNS KNOTS VTUN 80 = = = = = = = 190 except + 4.12" heigh K13+H1.8.1+I1+E1.0(0 psi)/Solid cap, K13+H1.9.0+E1.2 (0 psi)/Standard 10' Kl3+Hl.0+El.2 (0 psi)/Baseline with ejector tube moved aft K13+H1.0+E3.5.2 (40 psi)/Wide chord psi)/16" fabri-K<sub>13</sub>+H<sub>1.0</sub>+E<sub>3.5.2</sub> (150 psi)/Same as 184 with 150 psi air K<sub>13</sub>+H<sub>1,0</sub>+E<sub>3,5,4</sub> (150 psi)/Like 185 Kl3+H1.8.2+I1+E1.0 (0 psi)/Same as with modified shroud 10" diam. 3.25" height Kl3+Hl.0+Il+El.0(0 psi)/Baseline with I, instr. ring K<sub>13</sub>+H<sub>1.0</sub>+W<sub>2.0</sub>+E<sub>1.0</sub>(0 psi)/Double slotted flapped wing K<sub>13</sub>+H<sub>1.0</sub>+W<sub>3.0</sub>+E<sub>1.0</sub>(0 psi)/Single cated frisbee with lip at 40 psi frisbee slotted flapped wing K13+H1.0+W4.0/Boom mounted stub CONFIGURATION/CONDITION 9 wing K13+H1.9.1+E1.2 179 181 186 180 182 183 184 185 187 188 189 190 NO.

p/q = = = = = = = -3.8 ANGLES -= = = = = MODEL = = = . 9 = = = = = = DISK LDG. 8 = = = = EVALUATION OF WAKE-ALTERING DEVICES RPM MR/TR 1433/0 = = = = = TABLE 2 (CONTINUED) LIST OF TEST RUNS VTUN 80 = = = 2 = = K13+H1.11.1+I2+E1.0(150 psi)/Same as 194 with 150 psi air as cap, cap, K13+H1.11.1+I2+E1.0(0 psi)/7.6" cap as as K<sub>13</sub>+H<sub>1.11.1</sub>+I<sub>2</sub>+E<sub>4.0</sub> (0 psi)/Same as 194 except blowing tube 2" aft as 200 except center support cap K<sub>13</sub>+H<sub>1.11.2</sub>+I<sub>2</sub>/Baseline with I<sub>2</sub> and K<sub>13</sub>+H<sub>1,11,1</sub>+I<sub>2</sub>+E<sub>4,0</sub> (150 psi)/Same as 198 with 150 psi air K13+H1.11.2+I2+E4.0 (150 psi)/Same K13+H1.11.1+I2+E4.0 (40 psi)/Same 198 with 40 psi air K13+H1.11.1+I2+E1.0(20 psi)/Same K13+H1,11,1+12+E1,0(40 psi)/Same 194 with 40 psi air (0 psi)/10" K<sub>13</sub>+H<sub>1.0,2</sub>+I<sub>1</sub>+E<sub>1.0</sub> (0 psi)/10" no underbody, 1.25" gap CONFIGURATION/CONDITION no underbody, 1.87" gap underbody, 1.25" gap 194 with 20 psi air K13+H1.0.2+I1+E1.0 195 191 193 194 196 197 198 199 200 202 NO. 201

TAIL

Off

=

=

=

=

=

=

:

=

=

=

Kl3+H1.0+E5.0(0 psi)/Bifurcated air

duct baseline

no blowing tube

203

TABLE 2 (CONTINUED) LIST OF TEST RUNS
EVALUATION OF WAKE-ALTERING DEVICES

TAIL	ROTOR	Off									
MR HT.	p/q	8	•	#(D) (1)							
MODEL	• 4	-3.8		•		•					
MODEL	90	9	•	0 . E	•	2					
DISK LDG. psf		8		<b>E</b>	•	•	# # # # # # # # # # # # # # # # # # #				
RPM	MR/TR	1433/0		•			08 208 208			\$41	
VTUN	KNOTS	80		п р		•	=				
CONFIGURATION/CONDITION		Kl3+Hl.0+E5.0 (150 psi)/Bifurcated duct with 150 psi air	K <sub>13</sub> +H <sub>1.0</sub> +E <sub>5.0</sub> (40 psi)/Same as 204 with 40 psi air		K <sub>13</sub> +H <sub>1.2.2</sub> +I <sub>1</sub> +E <sub>1.0</sub> (0 psi)/Same as 207 except 0.55" gap	210 K <sub>13</sub> +H <sub>1.15,1</sub> +I <sub>1</sub> +E <sub>1.0</sub> (0 psi)/Repeat of 189	K <sub>13</sub> +H <sub>1.14.1</sub> +I <sub>1</sub> +E <sub>1.0</sub> (0 psi)/Like 189 and 210 except cap is oper			-0.2.3	
RUN	NO.	204	205	207	77	210	211	0			

TABLE 3

INDEX TO RAKE POSITIONS

RUN NUMBER	POINT	WATER LINE	MODEL STATION	LINE	FIGURE
111	20 21 22 24 26 28 30 32 34 36	53.5 "" "" ""	103.1 105.0 107.0 109.0 111.0 112.9 114.9 116.9 118.9	-7.25	
112	2 4 6 8 10 12	48.9 50.8 52.7 54.5 56.2 57.2	107.3	-7.25	1
113	2 4 6 8 10 11	51.7 52.3 52.8 53.3 53.9 53.3	103.3	-3.25 " " "	1
114	2 4 6 8 10	44.5 46.4 48.2 50.0 51.9	103.0	-3.25	1
115	3 4 6 9 10 12 14 16 18 20	52.9 52.0 50.0 48.0 46.0 44.1 42.1 53.0 54.0 55.0	124.7	-3.25	1

# TABLE 3 (CONTINUED) INDEX TO RAKE POSITIONS

RUN NUMBER	TEST POINT	WATER	MODEL STATION	BUTT	LOCATION FIGURE
116	7	36.9	100.5	-17.5	1
117	2 4 6 8 10	37.6 37.3	100.5	-16.0 -14.0 -12.0 -10.0 - 8.0	1
118	2	37.6	100.5	- 6.0	1
119	2 5 8 9 14 16 20 25	37.3 " " " " 51.5 52.3	99.6 "" "" 102.5 101.7	+ 6.0 8 10 14 16 17.5 -17.5	1 10-0
121	3 4 6 8 10	62.9 53.5 50.1 46.0 42.1	129.0	+ 5.7	2
135	2 4 6 8 10 12 14	56.9 54.5 52.5 50.5 48.5 46.5 44.5	106.3	- 5.7	3
136	2 4 6 8 10 12 14 17 18 19	56.5 54.5 52.5 50.6 48.5 46.5 44.5 37.1 39.0 41.0	104.0	- 8.0	4

TABLE 3 (CONTINUED)

INDEX TO RAKE POSITIONS

RUN NUMBER	TEST POINT	WATER	MODEL STATION	BUTT	LOCATION FIGURE
137	3 5 7 9 11 13	38.7 39.9 42.0 44.0 46.0 48.0 50.0	98.4 100.5 103.6	- 8.0	5
	17 19	52.0 54.0	H H	# #	477
138-41, 143	2 3 4 5 6 7 8 9	38.8 40.0 42.0 44.0 46.0 48.0 50.0 52.0 54.0	98.4 100.5 103.6	- 8.0	5
142	7 8 9 10	37.8 40.2 42.0	98.4	- 8.0	5
	11 12 13 14 15 16 17	44.0 46.0 48.0 50.0 52.0 54.0 56.8	103.6	11 11 11 11 11	61.15
	0.8	.0.401			35.1
		- 1	0.16		

TABLE 3 (CONTINUED)

INDEX TO RAKE POSITIONS

RUN NUMBER	POINT	WATER	MODEL STATION	BUTT	LOCATION
149-151	2 3 4 5 6 7 8	38.8 40.0 42.0	98.5	- 8.0	5
	5	44.0	103.5	H H	
	8	48.0 50.0 52.0	"	11	
	10	54.0	"	•	
152-6, 158 161-4, 166 167, 169-71 175, 177-9 180,182,184 186-8, 190	2 3 4 5 6 7	42.9 44.9 46.9 48.9 50.9 52.9	97.9 100.6 104.6	0.0	6
191,193,194 196,198,201 204,207,208 211	8 9	54.9 56.9	"		N C 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
159	1 2 3 4 5	54.9 52.9 50.7 48.6 46.7	104.6	0.0	6
160,203	5 6. 7 8 9 10	42.9 44.9 46.9 48.9 50.9 52.9 54.9	97.9 100.6 104.6	0.0	6
165	3 4 5 6 7 8	44.9 42.9 46.9 48.9 50.9 52.9	97.9 100.6 104.6	0.0	6

TABLE 3 (CONTINUED)

INDEX TO RAKE POSITIONS

RUN NUMBER	TEST POINT	WATER	MODEL STATION	LINE	FIGURE
168, 183	4	42.9	97.9	0.0	6
	4 5 6 7 8 9	44.9	"	"	
	6	46.9	100.6		
	7	48.9	1 204 6	"	
	8	50.9	104.6		
	10	52.9 54.9	"		
		-	4 3 3		
172	3	42.9	97.9	0.0	6
	4	44.9	"	"	
	6	44.9			
	7	46.9	100.6	" "	
	4 6 7 8 9	48.9			
	10	50.9	104.6		
	11	52.9 54.9	u		The State of
	11	34.9	1 E E		
173,174,176	1	42.9	97.9	0.0	6
185,195,197	2	44.9		"	
199,200,205	3	46.9	100.6		
210	4	48.9		i i	
	5	50.9	104.6		
	1 2 3 4 5 6 7	52.9 54.9	n		
		<del></del>			ļ
181	2 3 4 5 6 7 9	42.9	97.9	0.0	6
	3	44.9	100.6		
	-	48.9	100.6	n	Ter ha
	6	50.9	104.6	n	
	7	52.9	101.0		
	9	54.9	100		
	10		E # 108	n e	
	11	"	"	n	
	12		90.2	"	
	13	42.9	97.9		
			6.728		
		1 6,400.5	100		
		0.101	100		

# TABLE 3 (CONTINUED) INDEX TO RAKE POSITIONS

RUN NUMBER	TEST POINT	WATER LINE	MODEL STATION	BUTT LINE	LOCATION FIGURE
189	29 30 31 32 33 34 35 36 37 38 39	42.9 44.9 46.9 48.9 50.9 50.9 52.9 54.9	97.9 100.6 " 104.6 100.6 104.6	0.0	6
202	3 4 5 6 7	43.4 44.9 46.9 48.9 50.9	97.9 100.6 104.6	0.0	6
				Management (Management )	
				100 - 200 -	

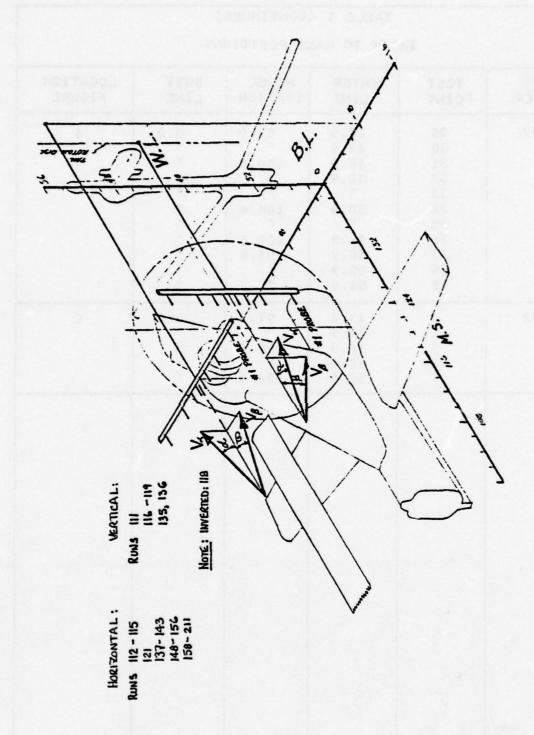
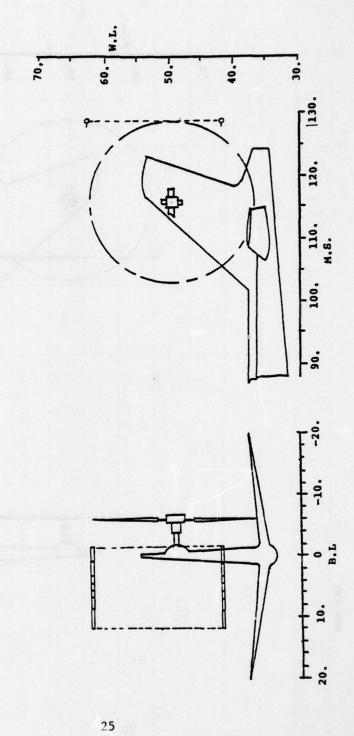


FIGURE 1 - RAKE ORIENTATION DIAGRAM



-HOT FILM RAKE LOCATIONS FIGURE 2

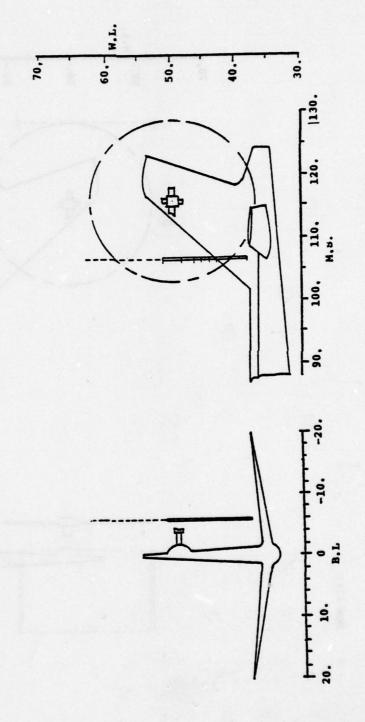


FIGURE 3 -HOT FILM RAKE LOCATIONS

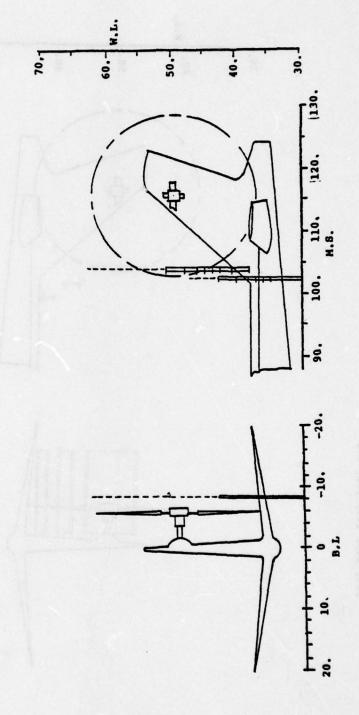


FIGURE 4 -HOT FILM RAKE LOCATIONS

RUN 137, 138, 139, 140, 141, 142, 143, 143, 148, 149, 150, 151

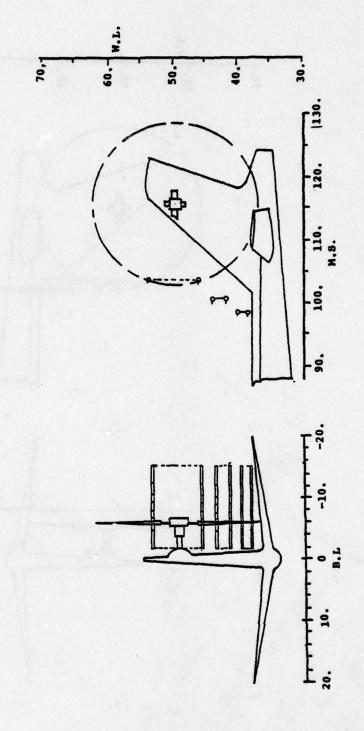


FIGURE 5 -HOT FILM RAKE LOCATIONS

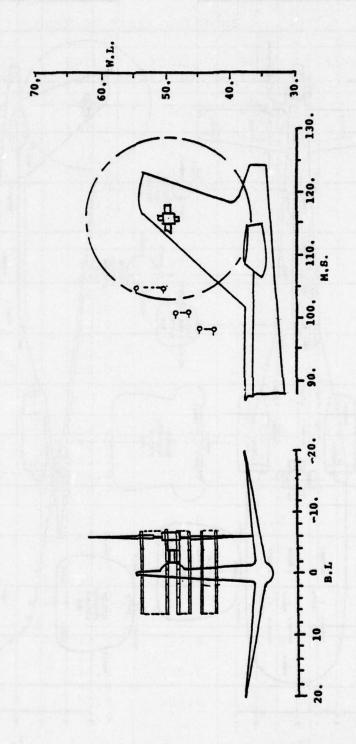
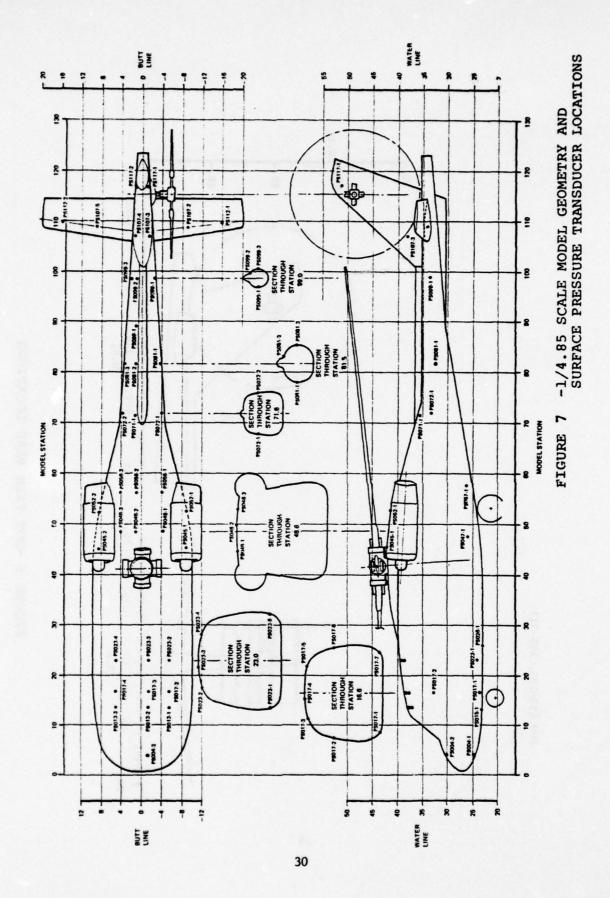
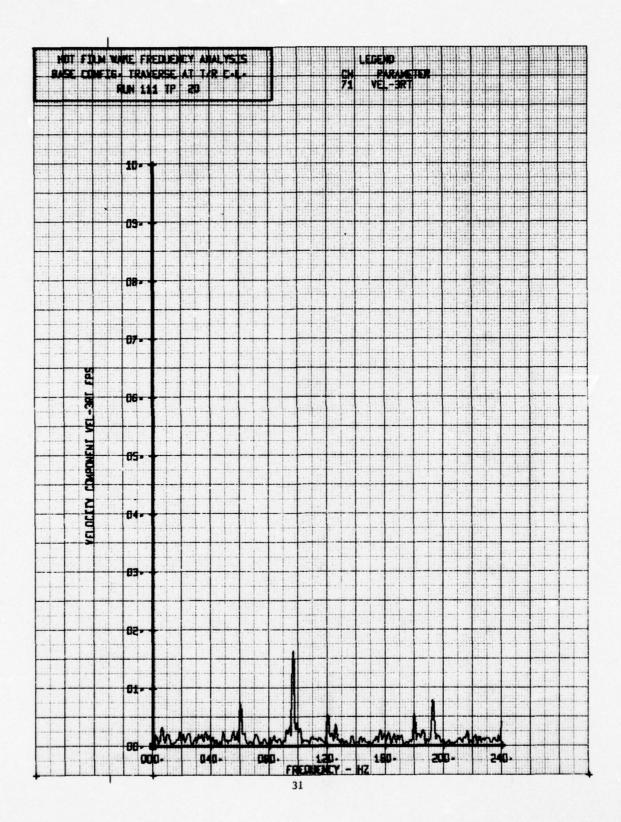
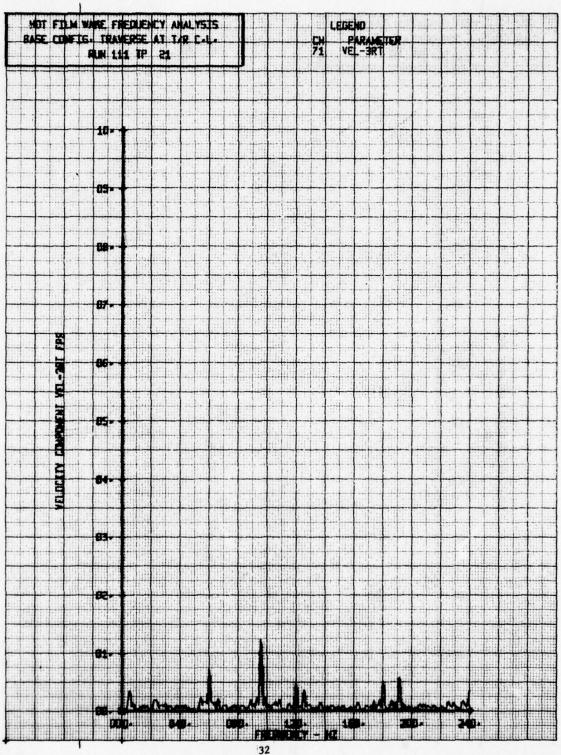
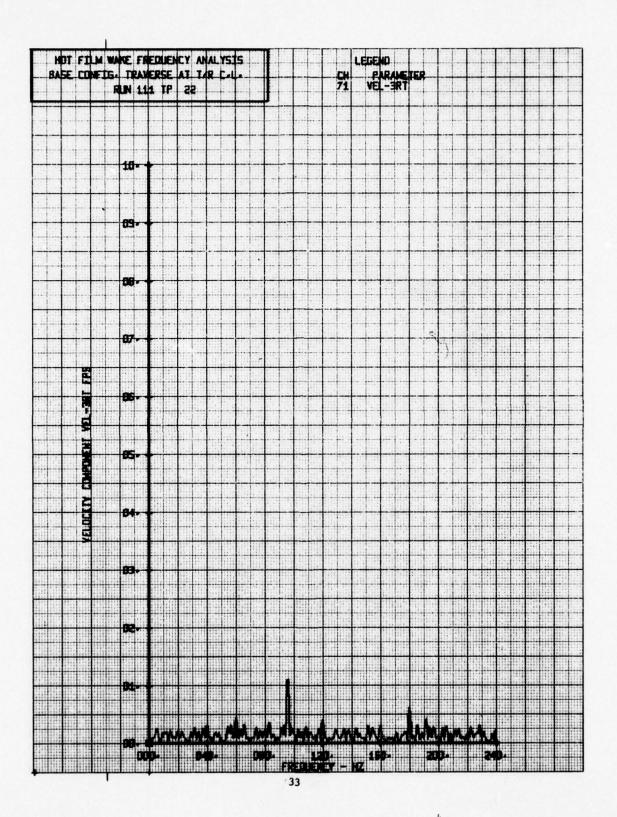


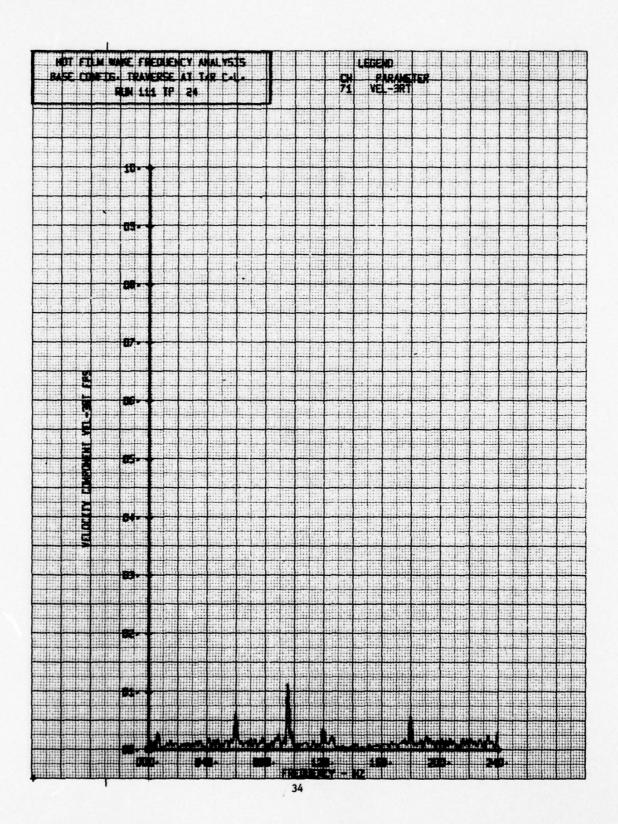
FIGURE 6 -HOT FILM RAKE LOCATIONS

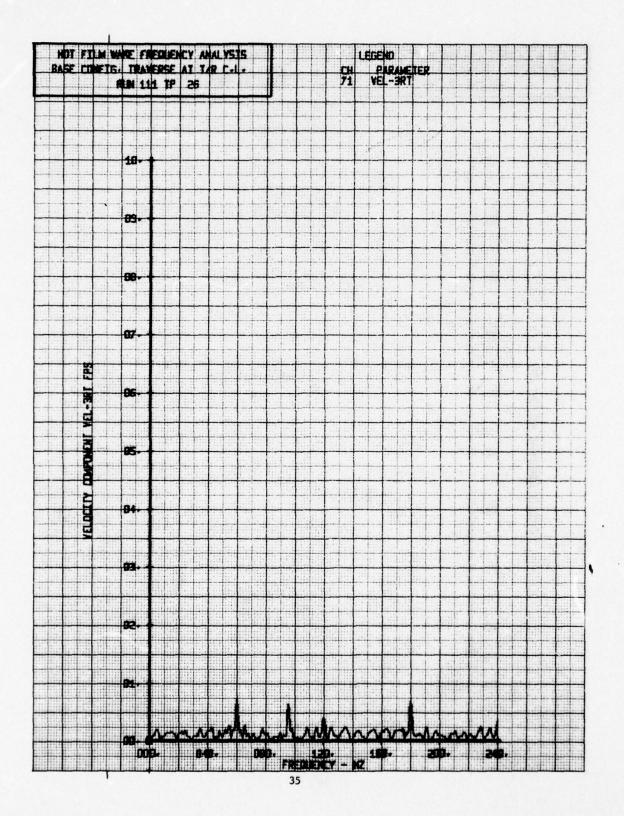


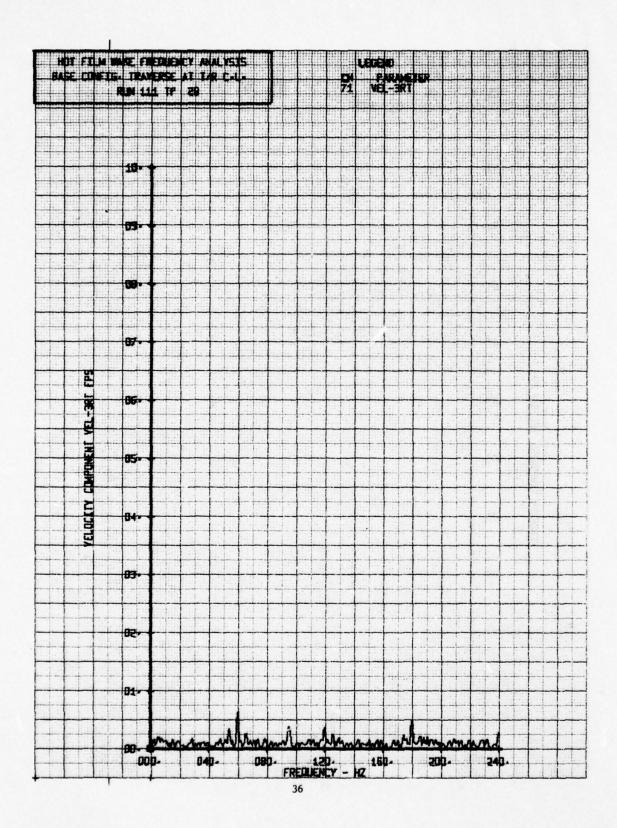


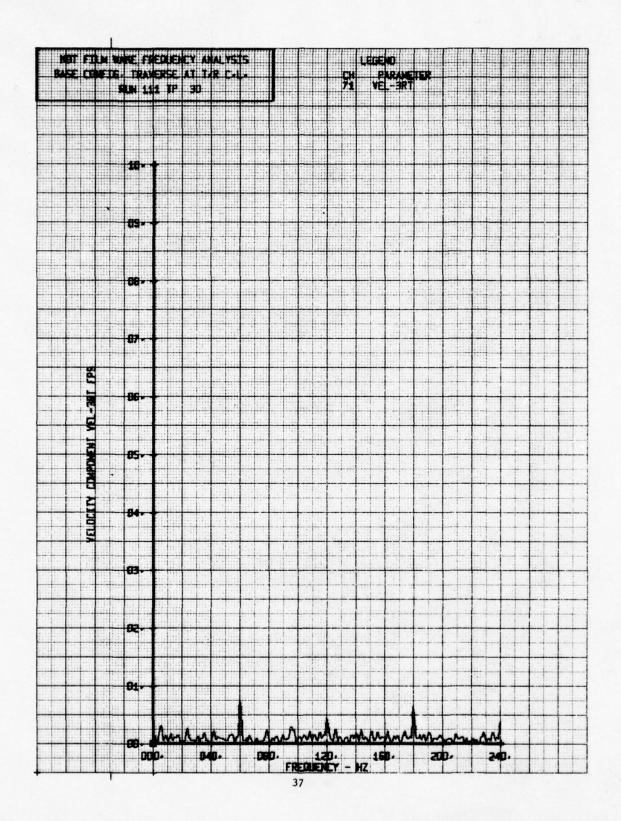


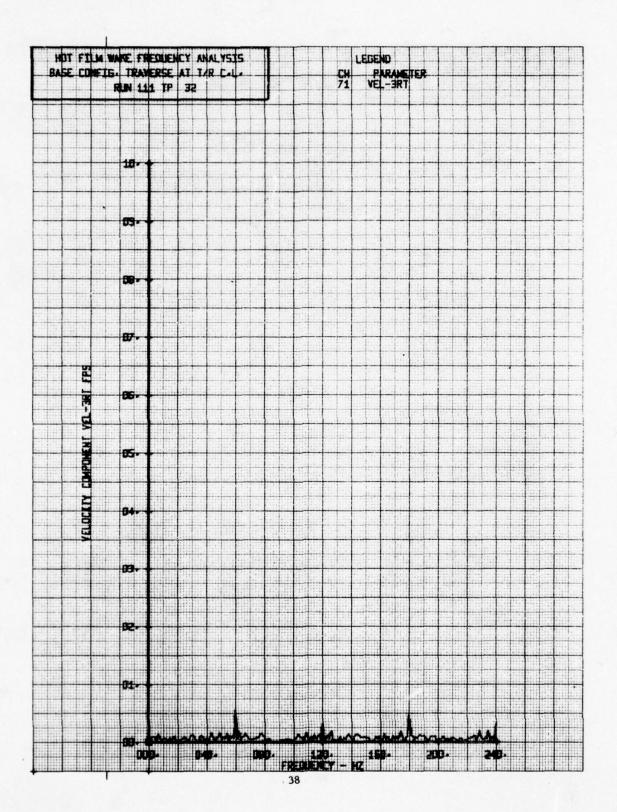


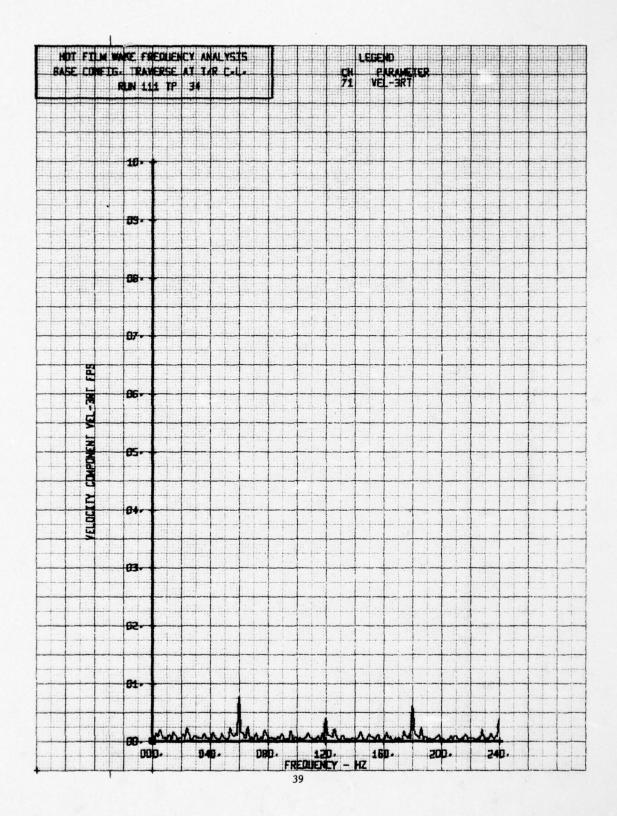


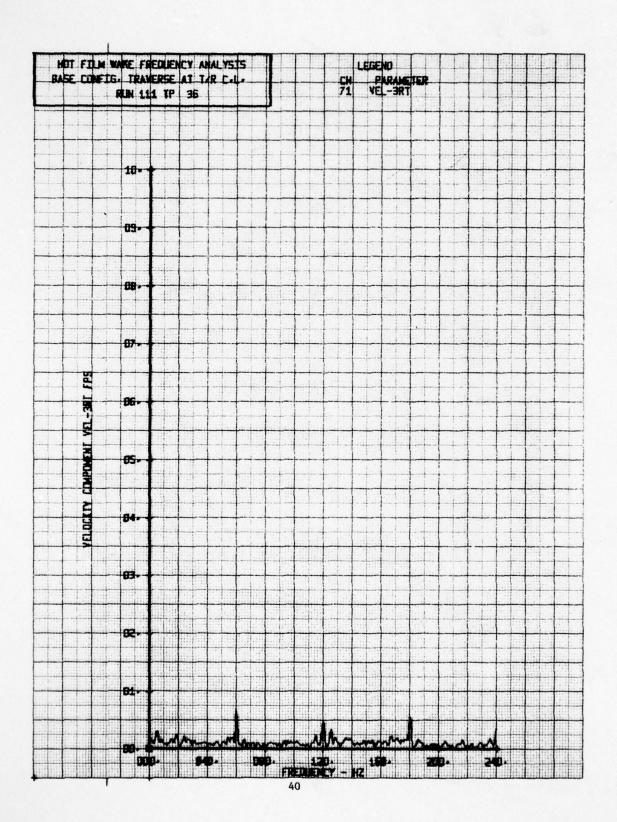


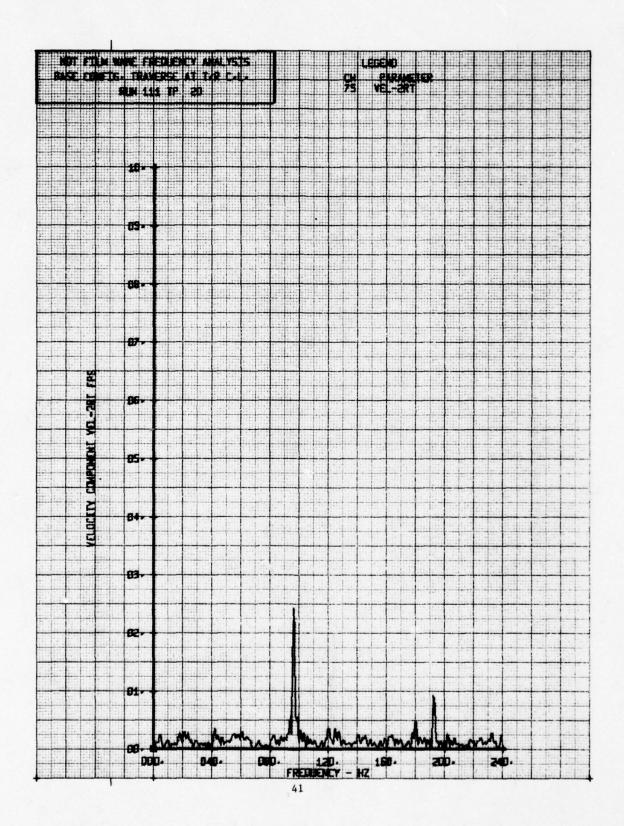


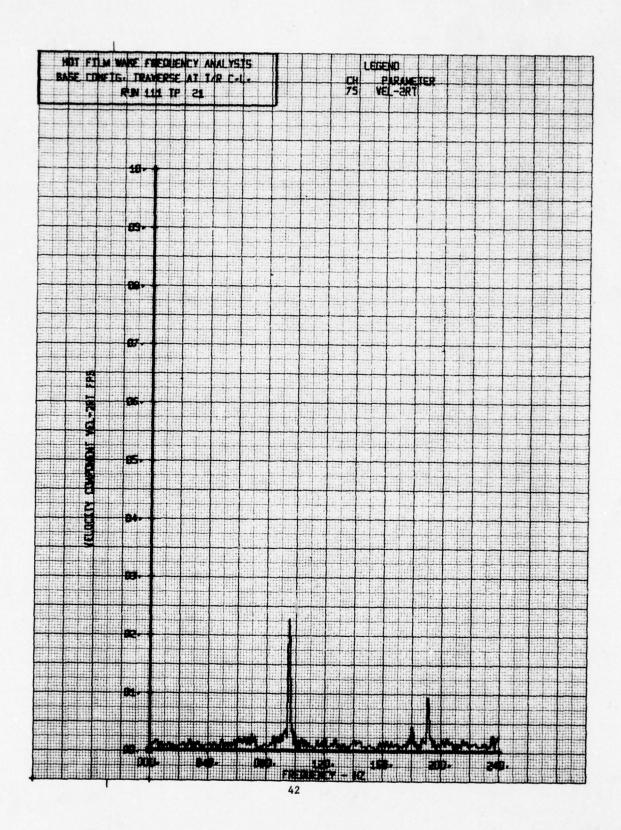


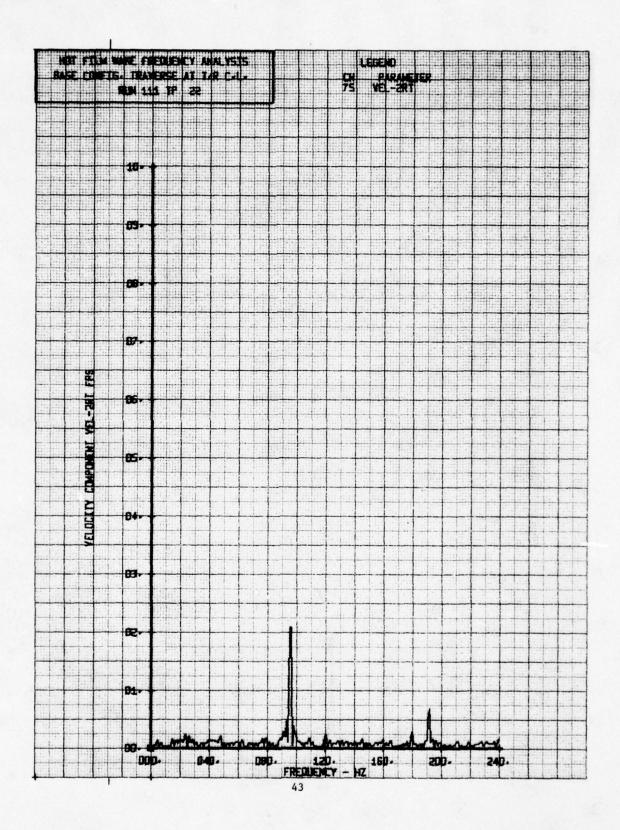


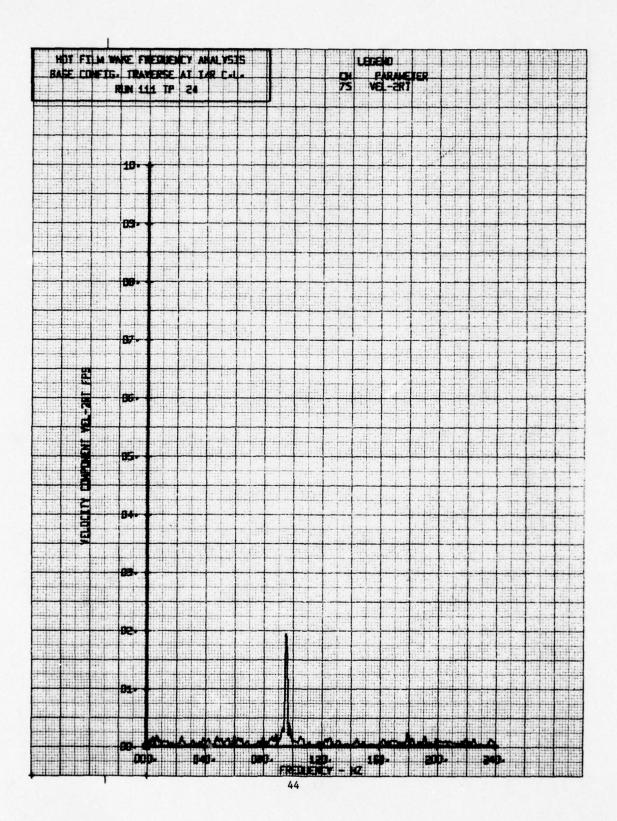


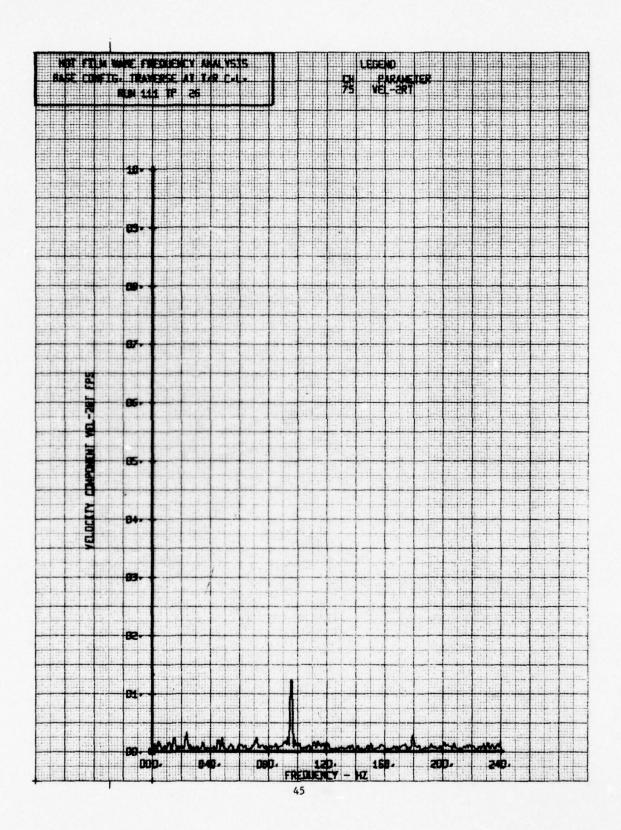


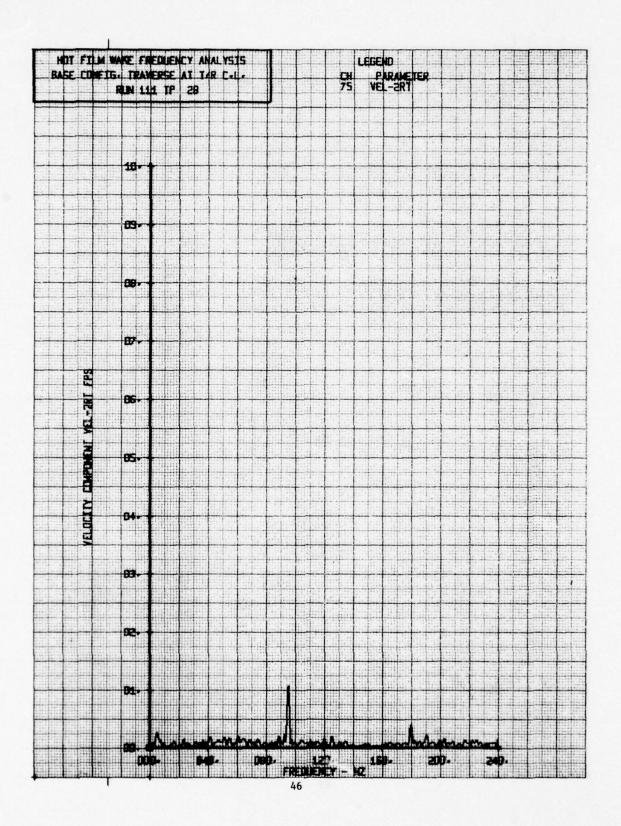


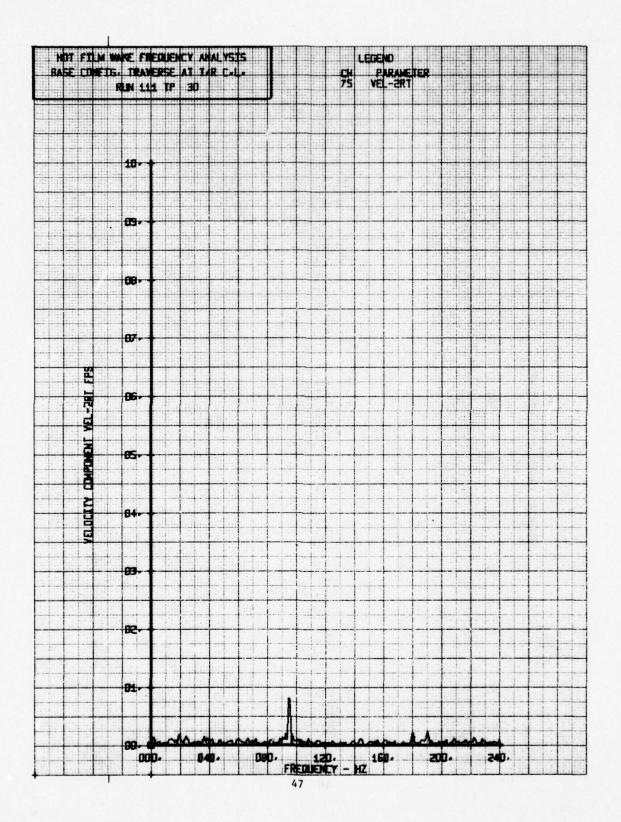


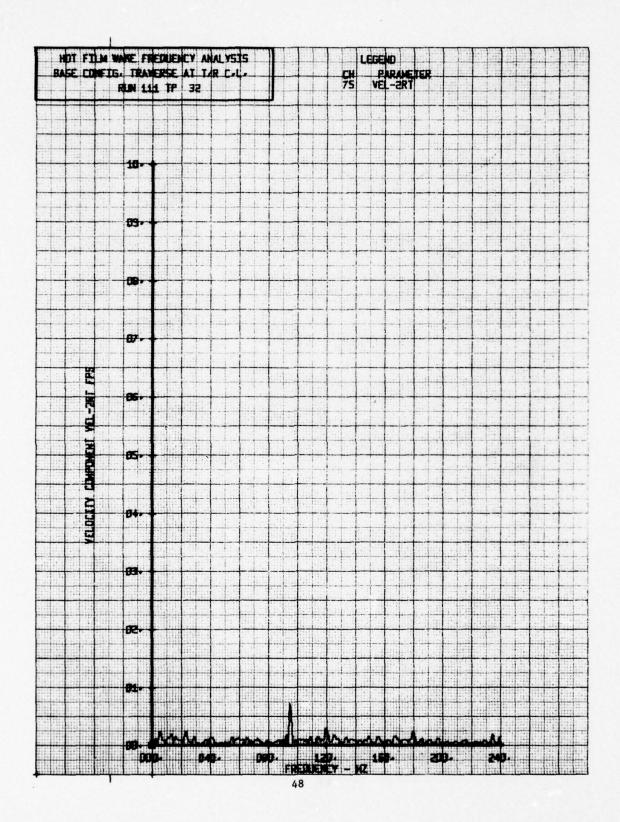




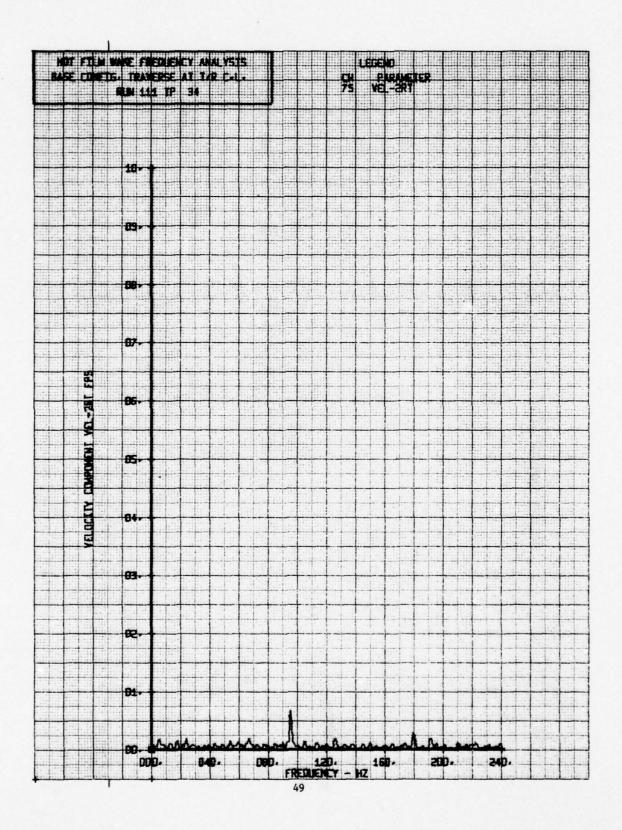


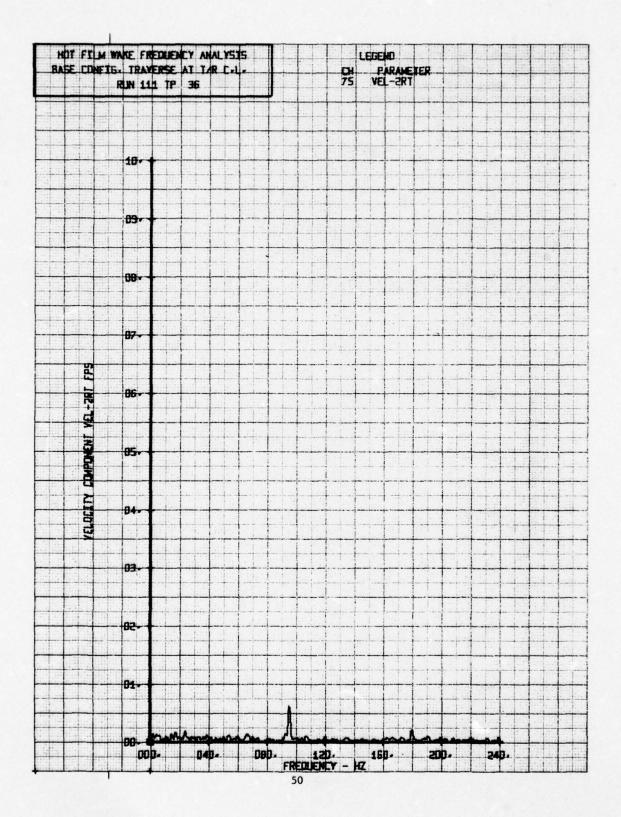


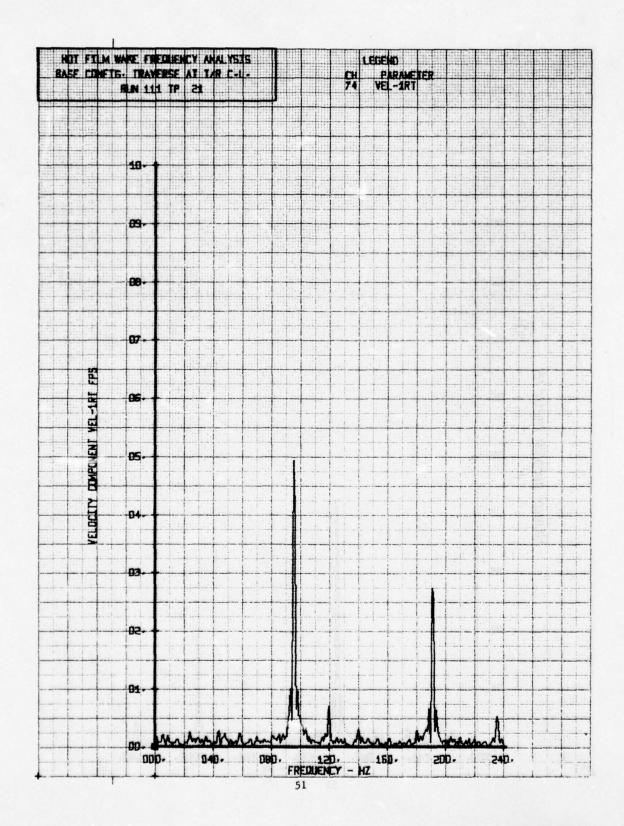


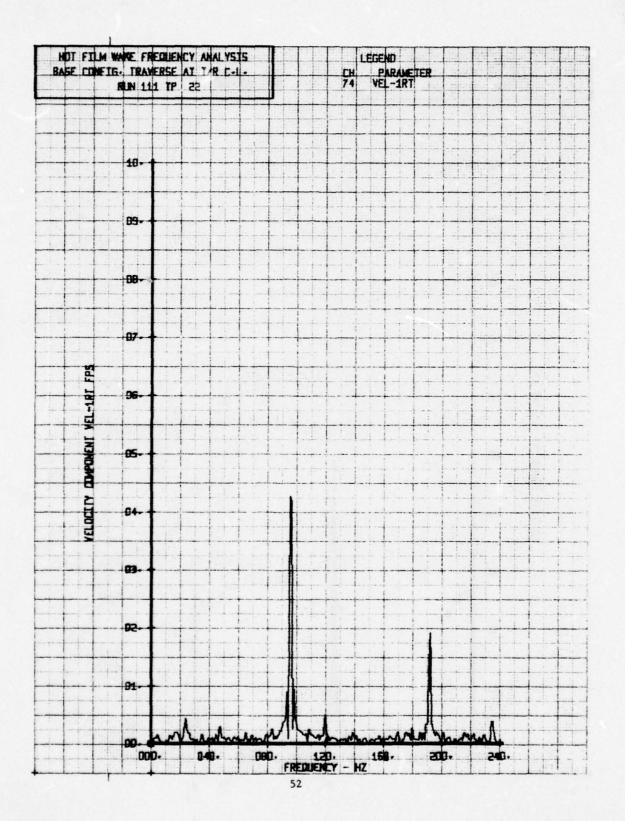


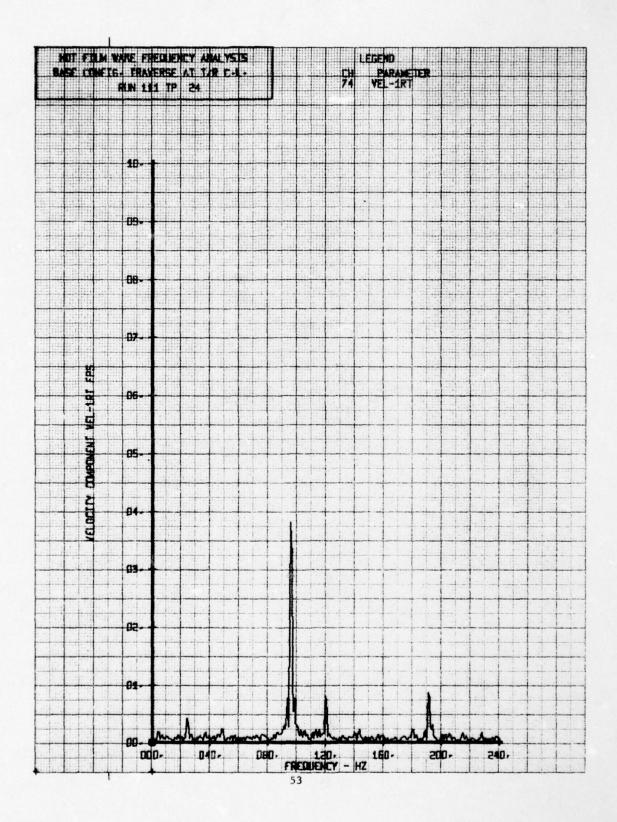
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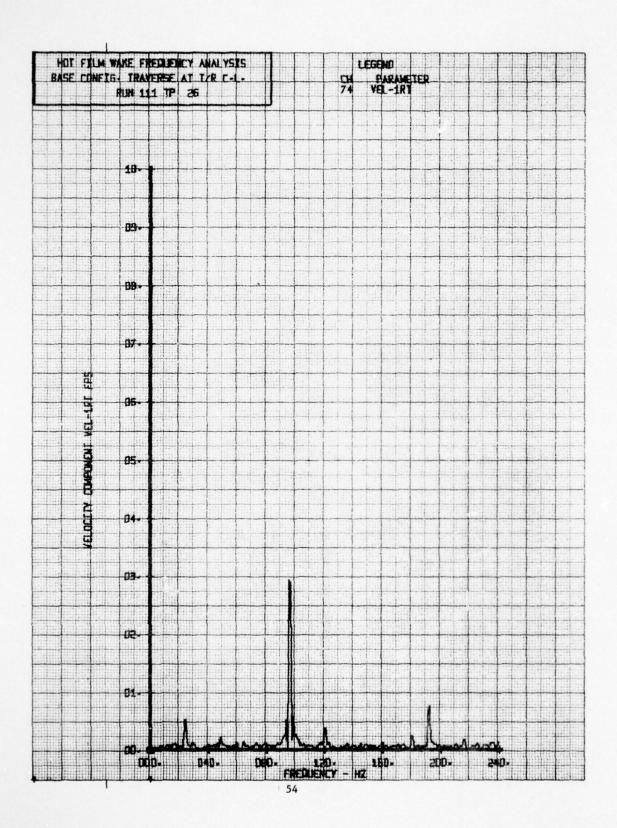


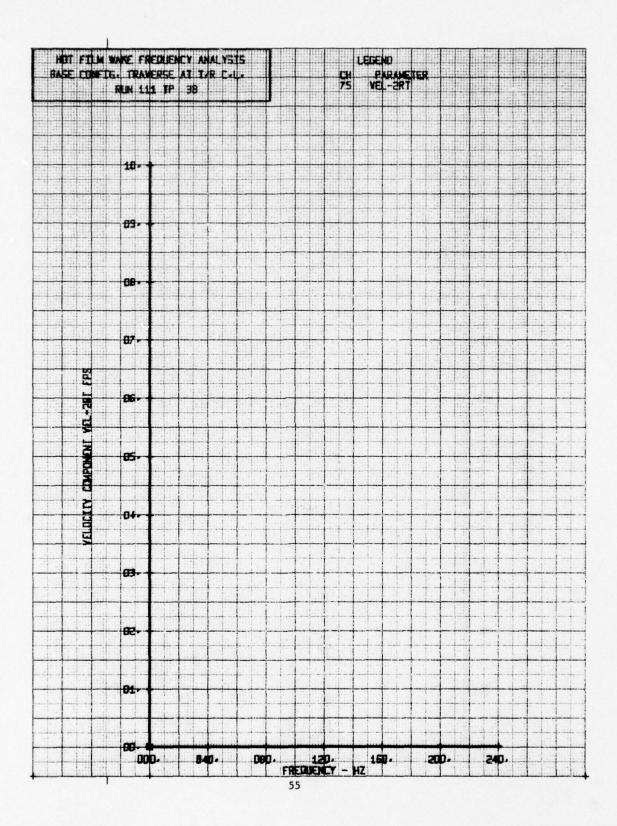


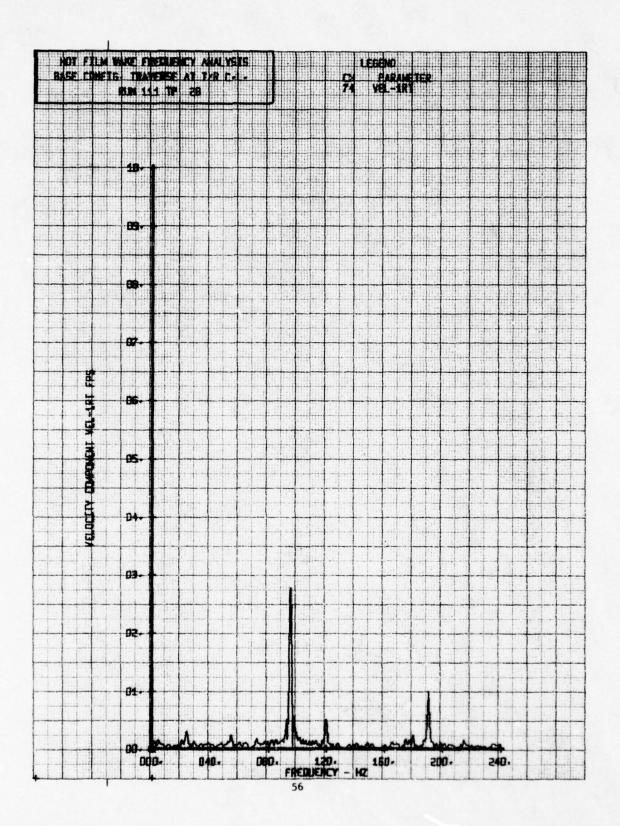


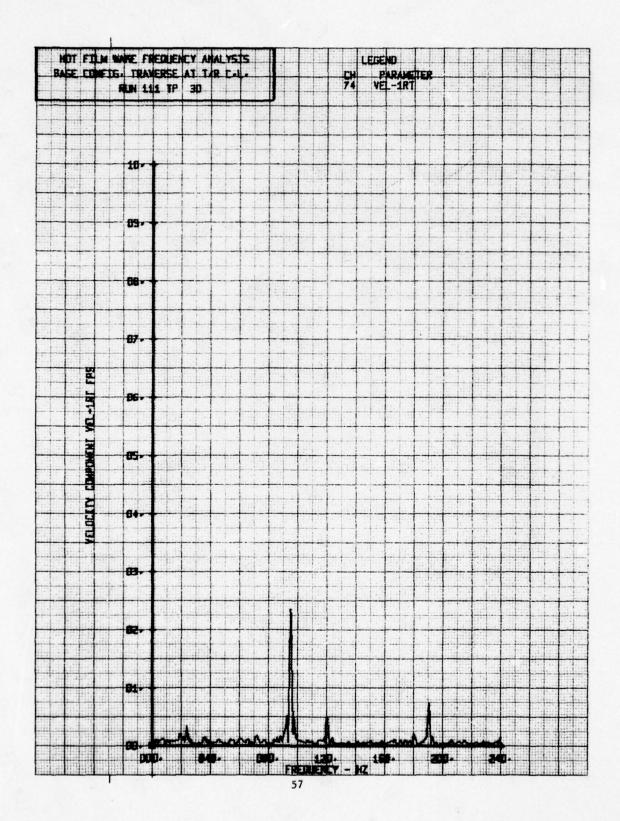


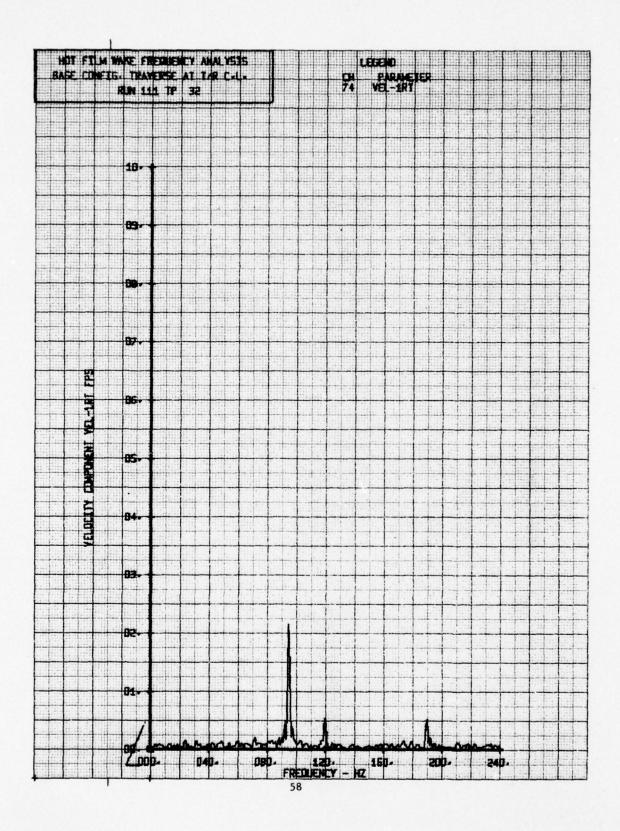


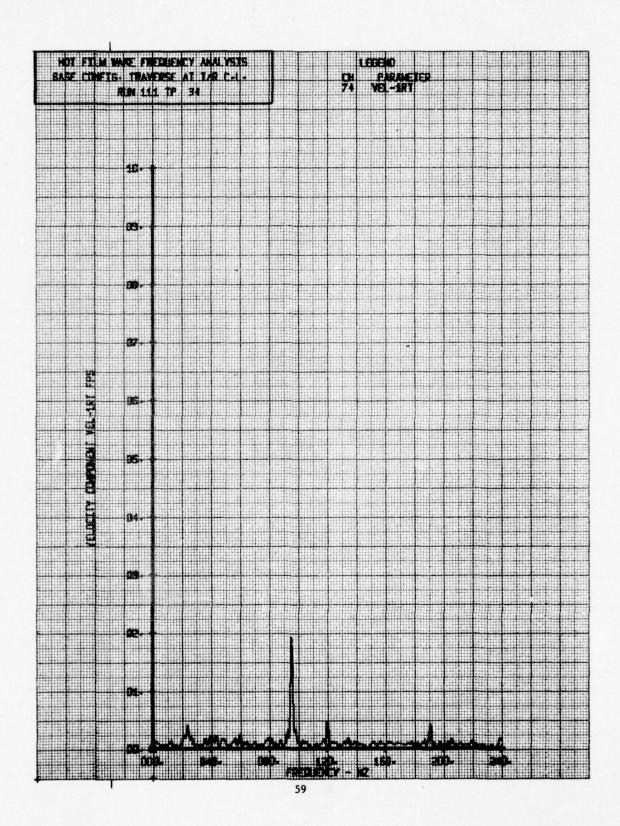


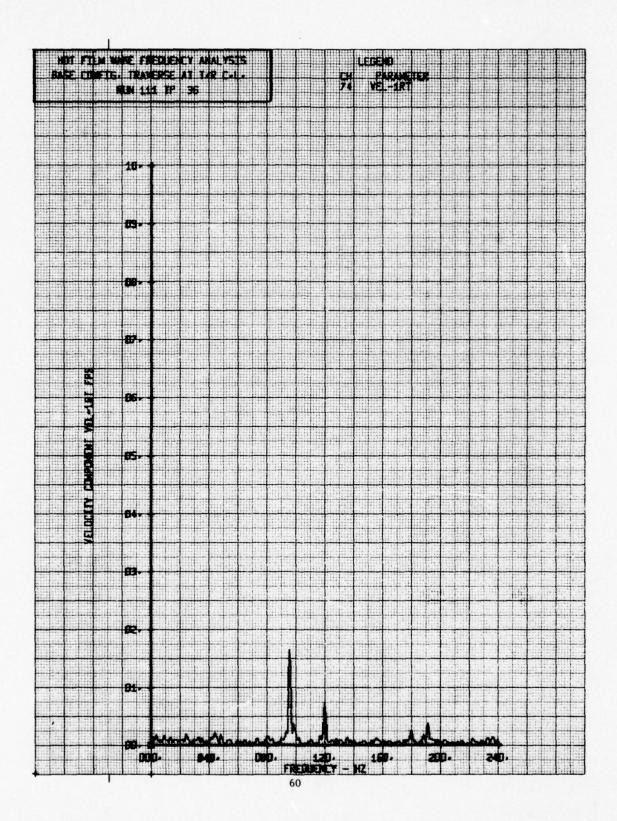


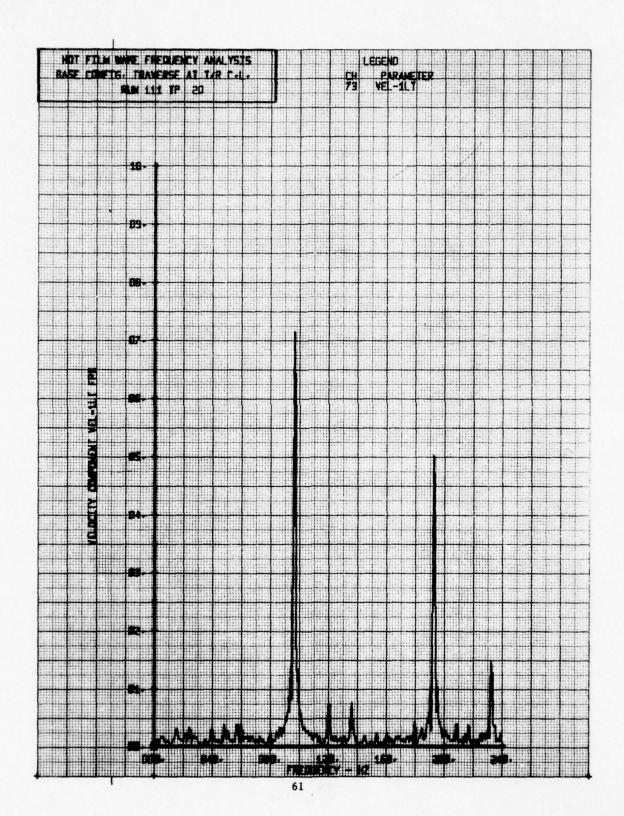


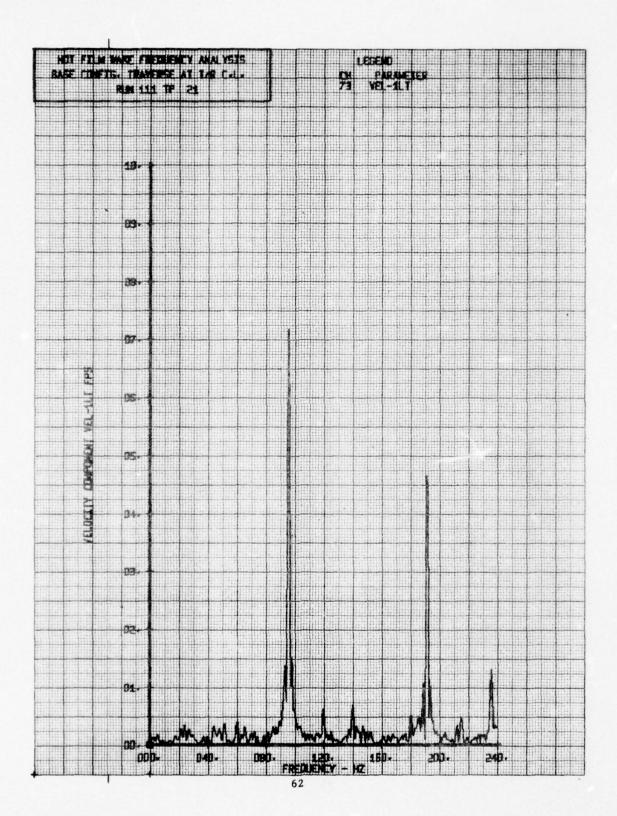


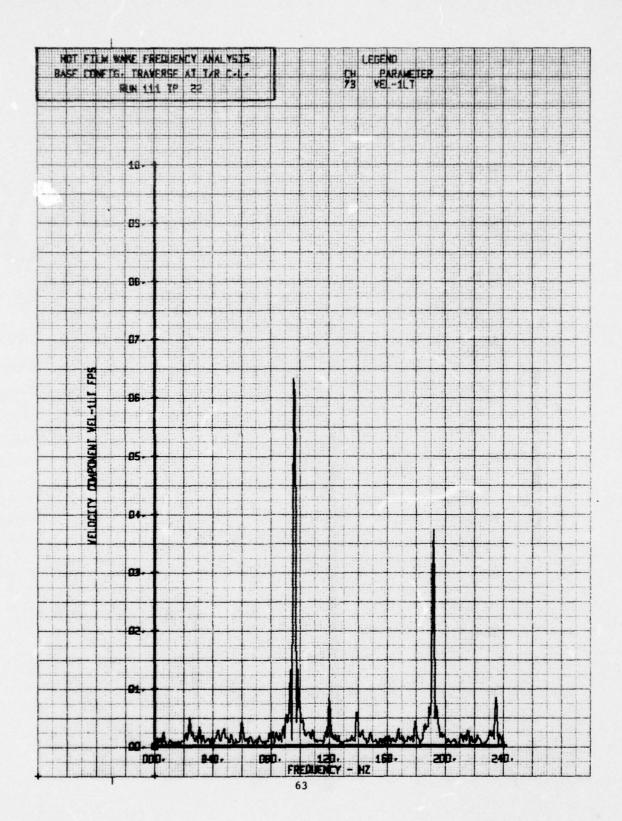


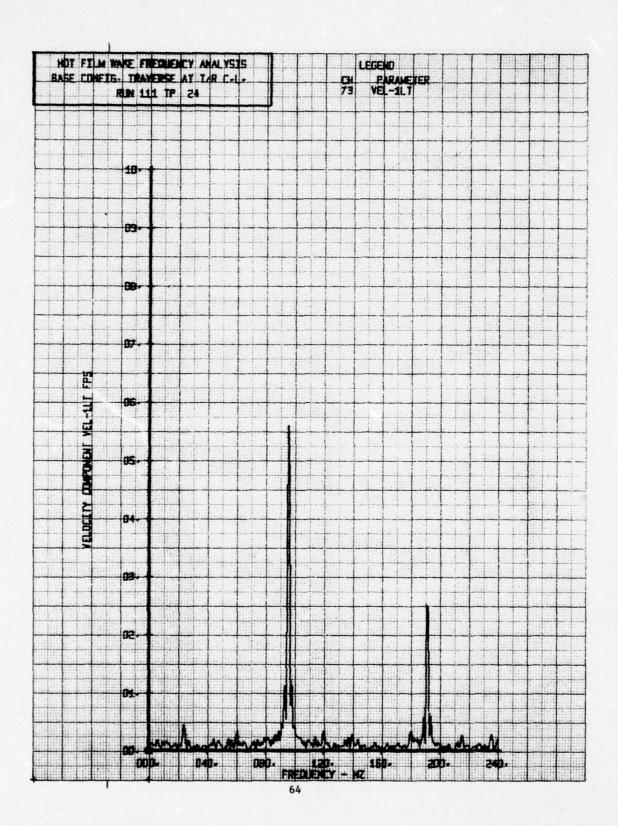


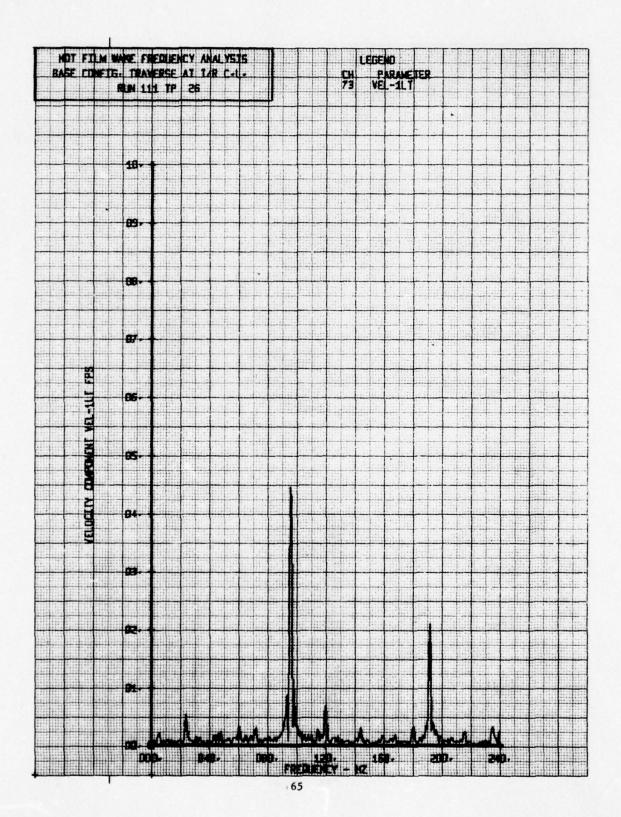


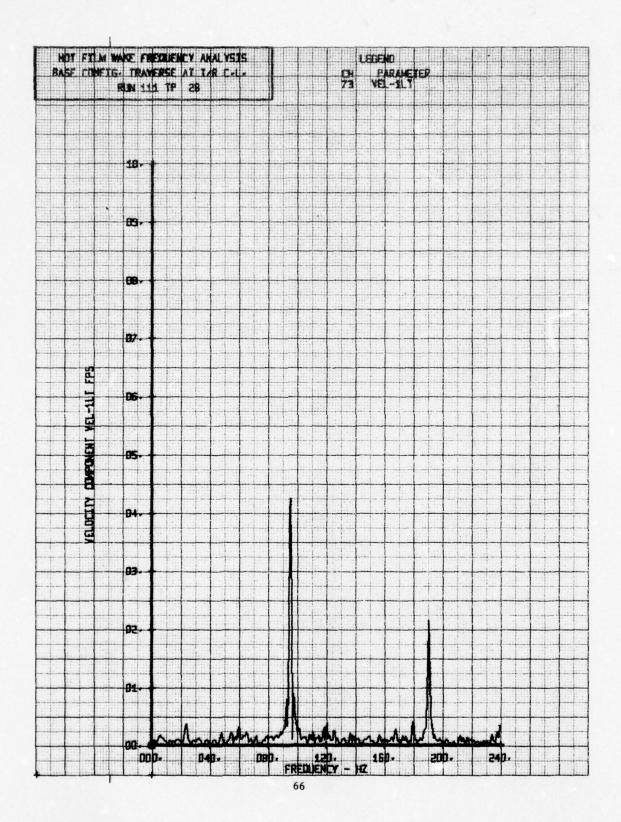


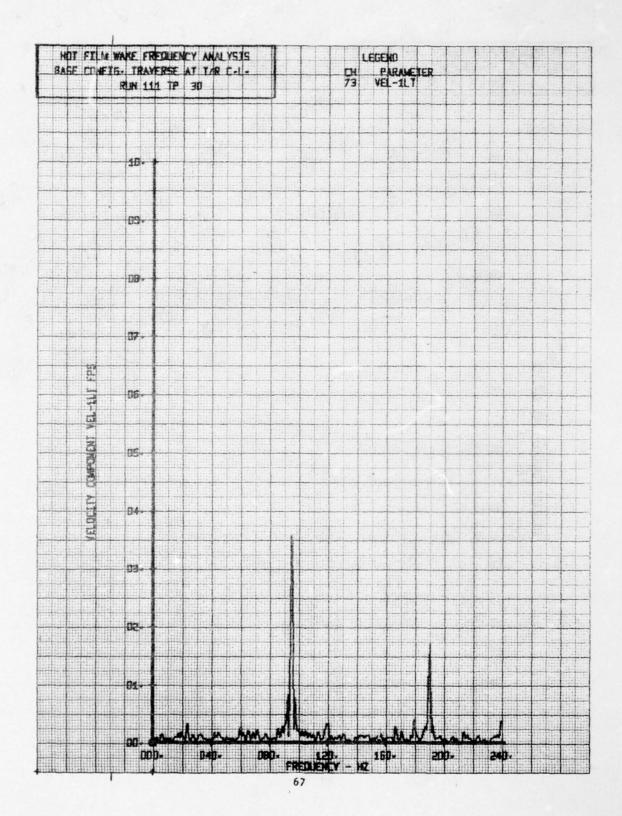


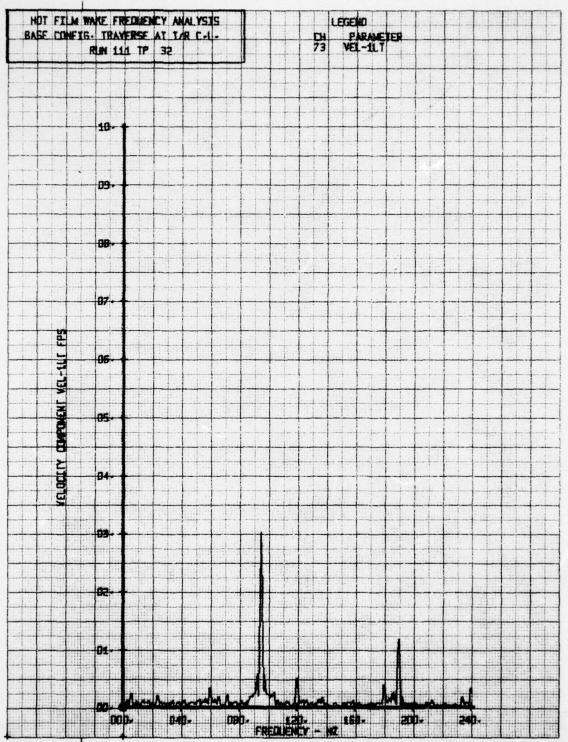


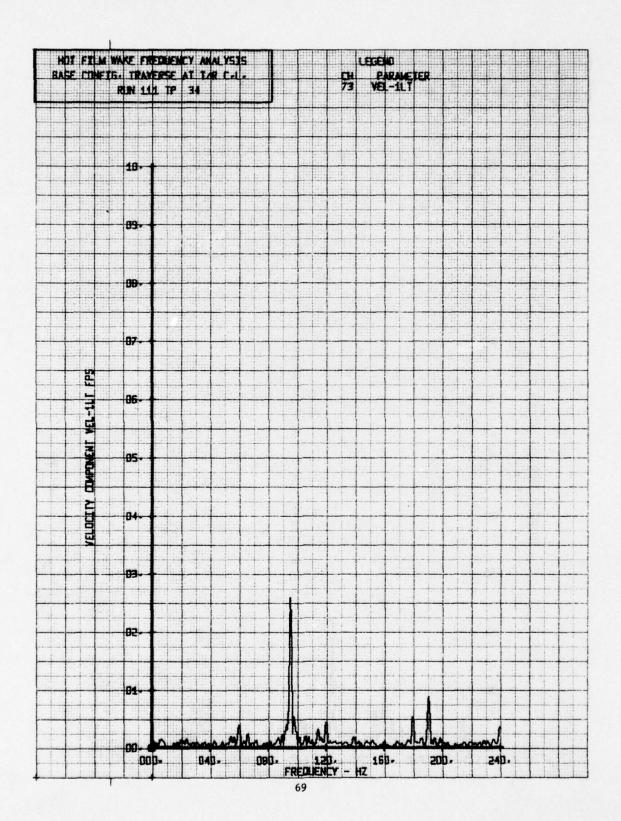


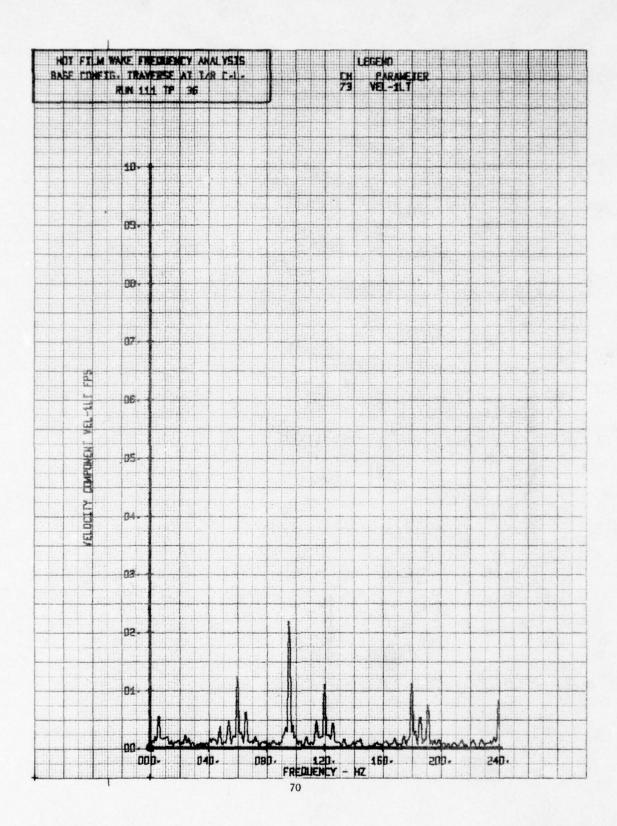


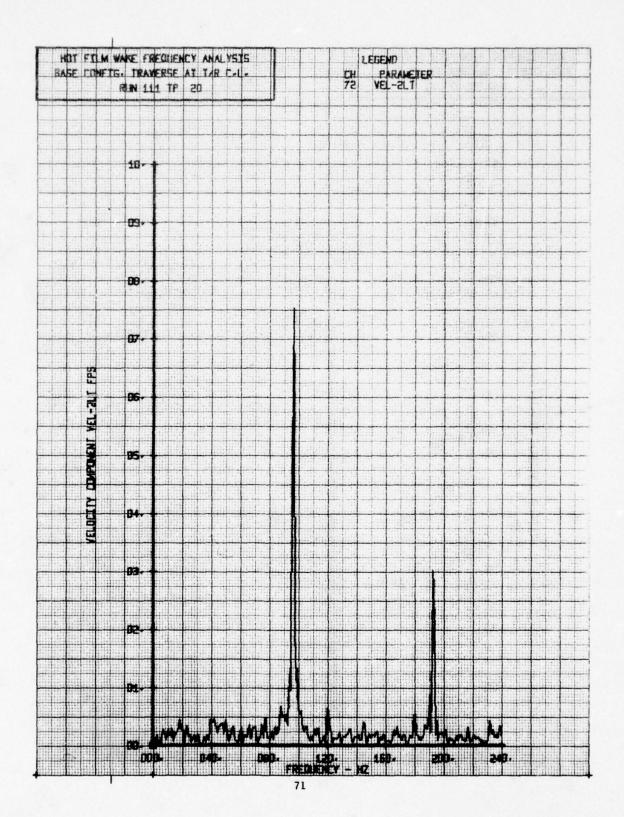


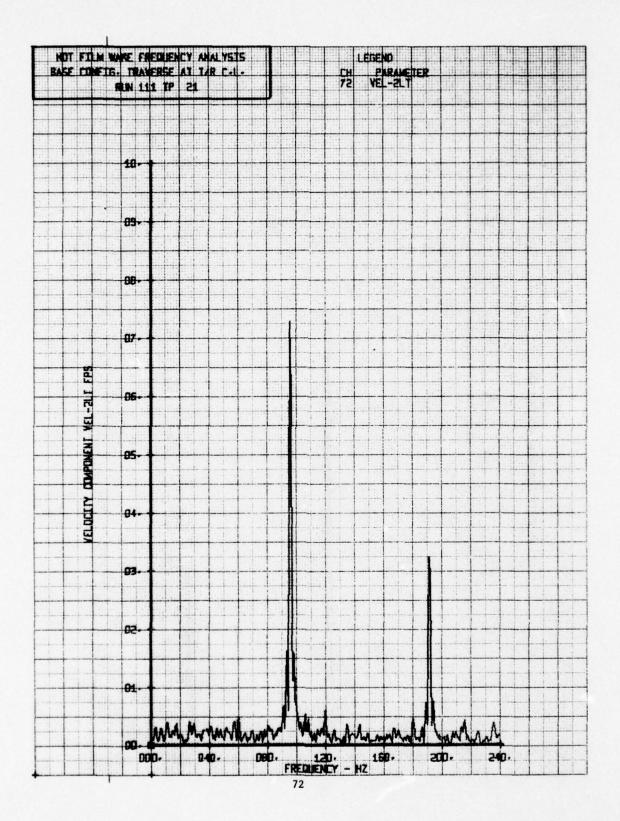


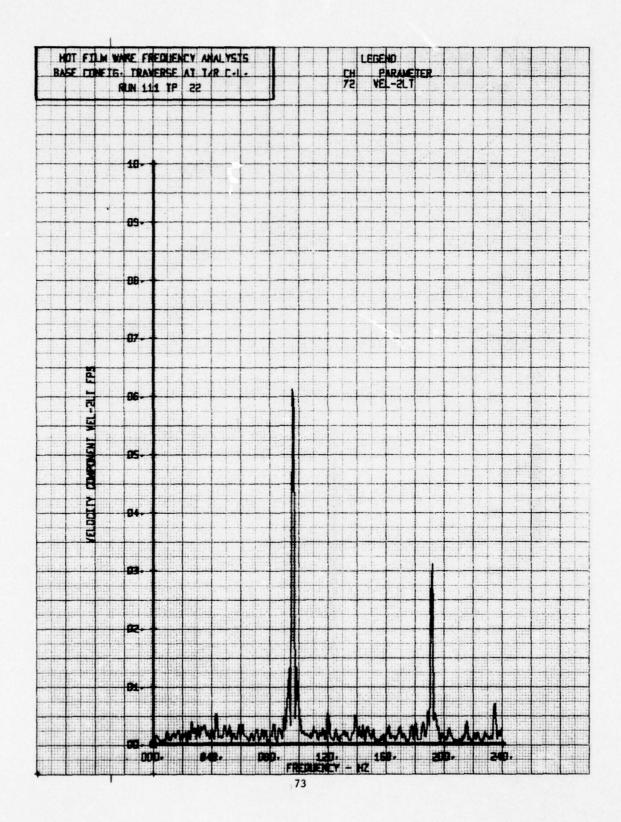


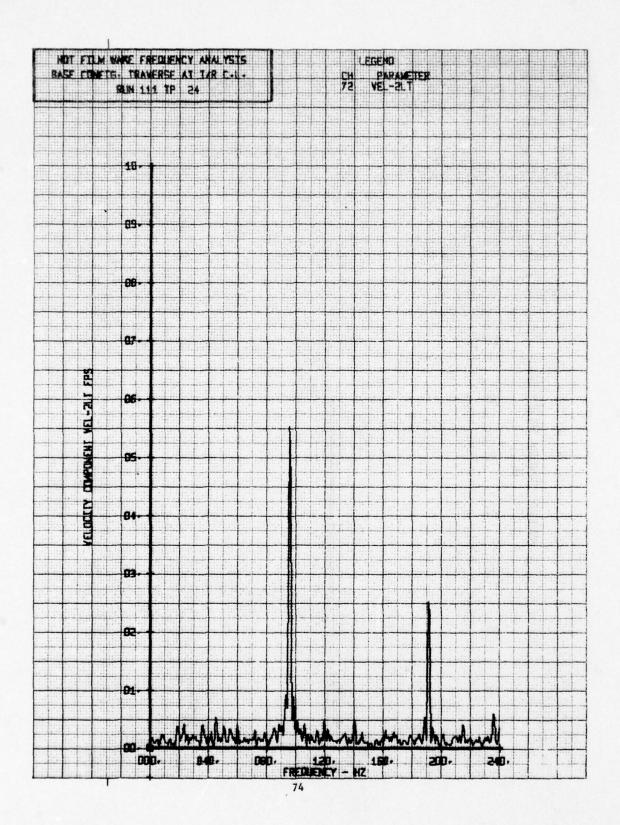


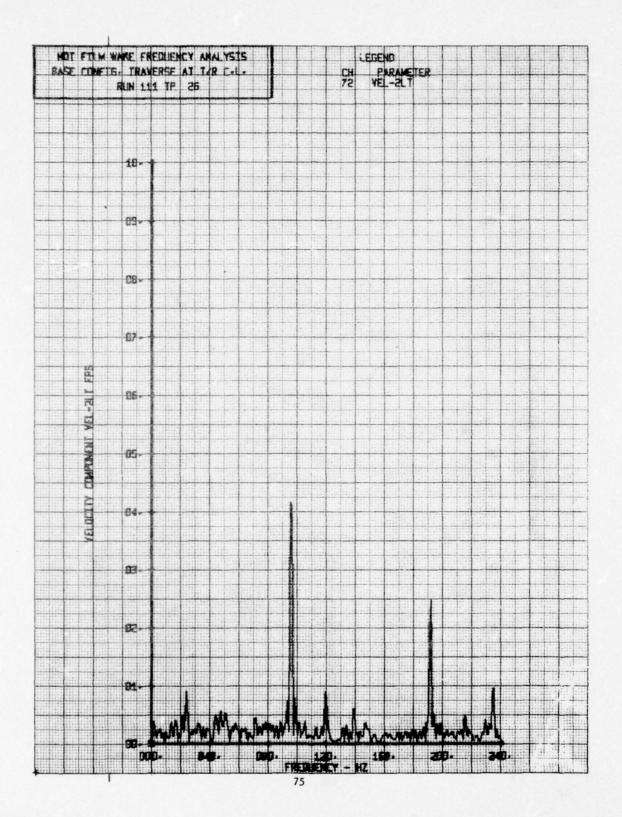


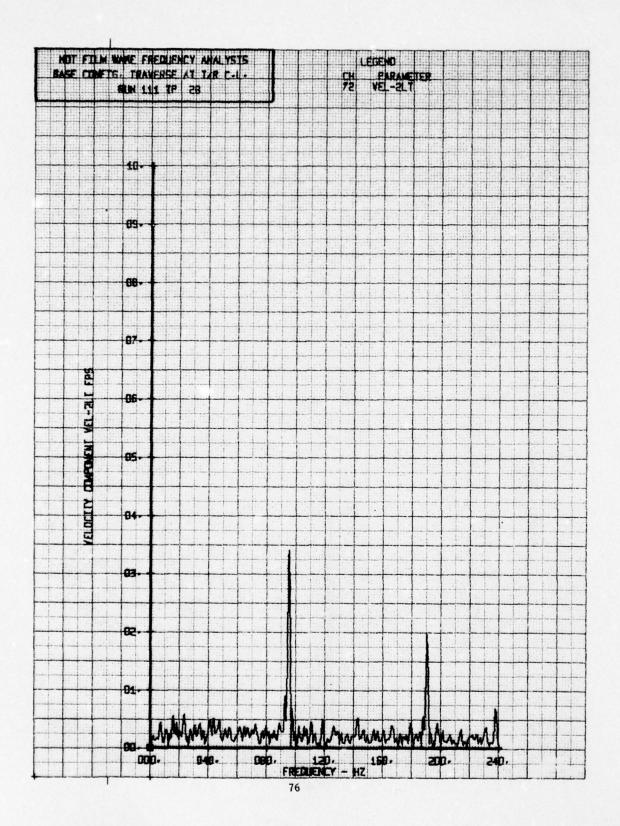


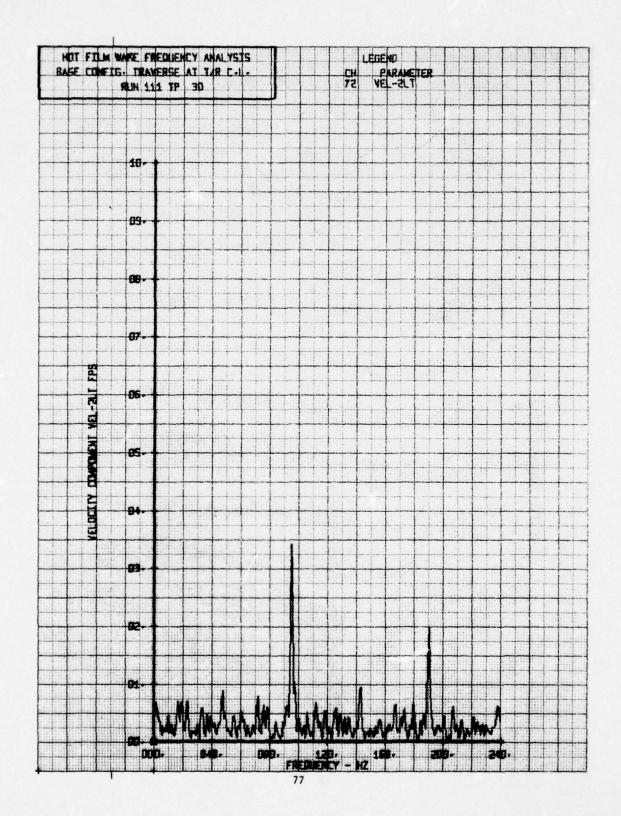


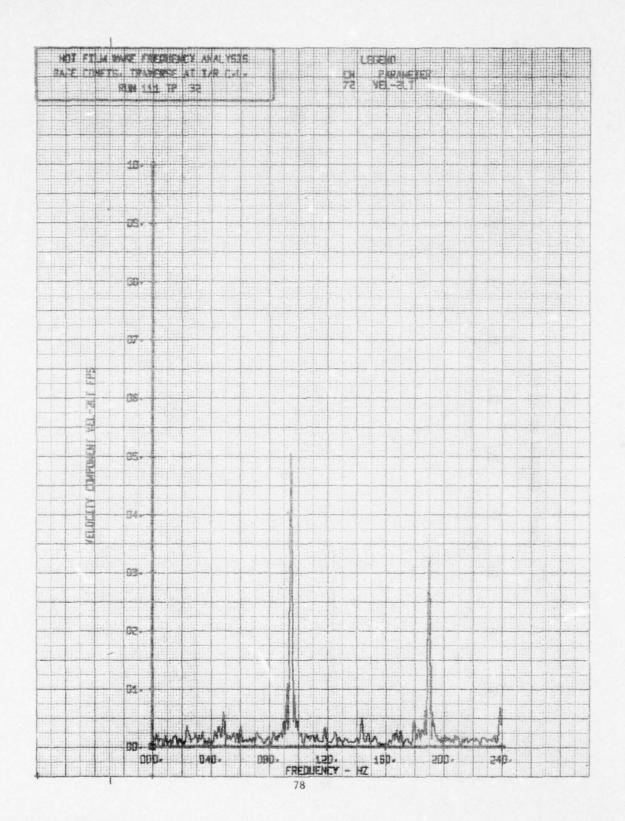


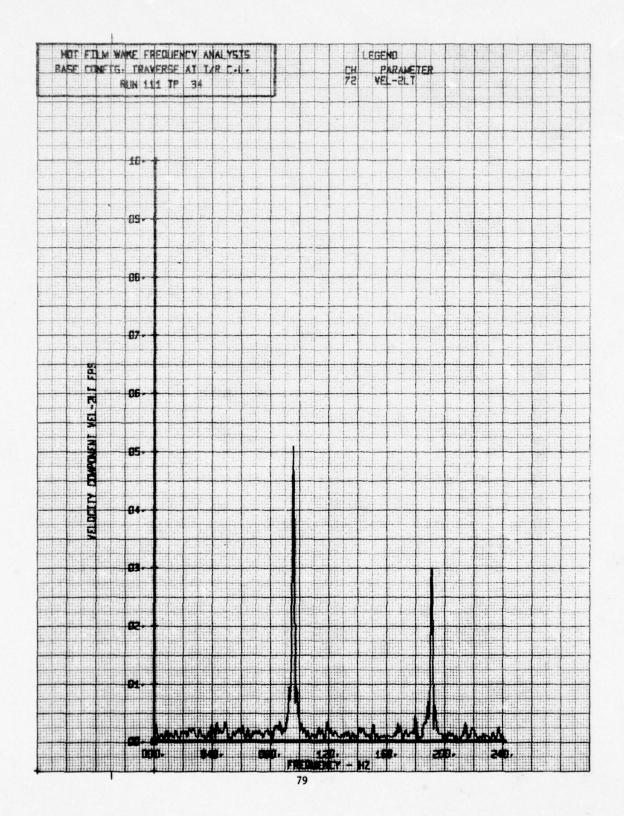


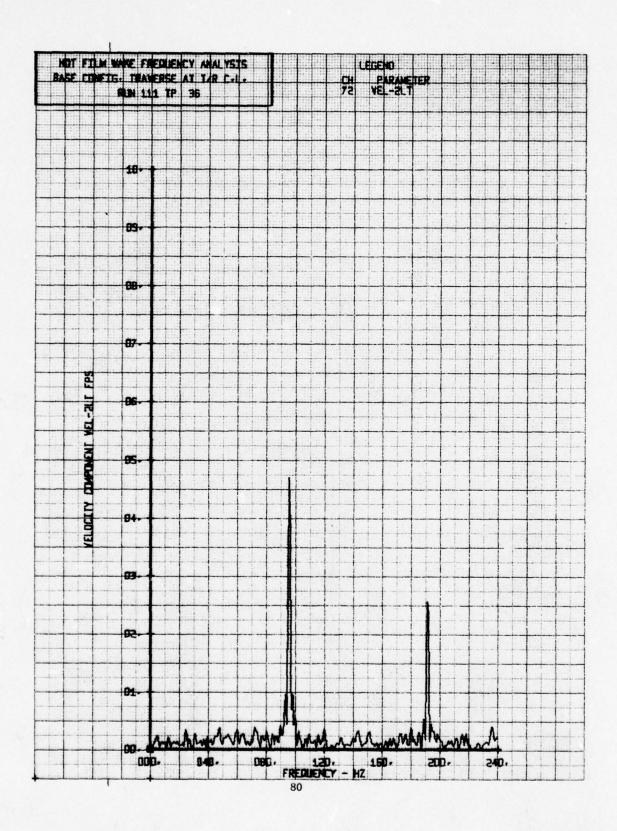


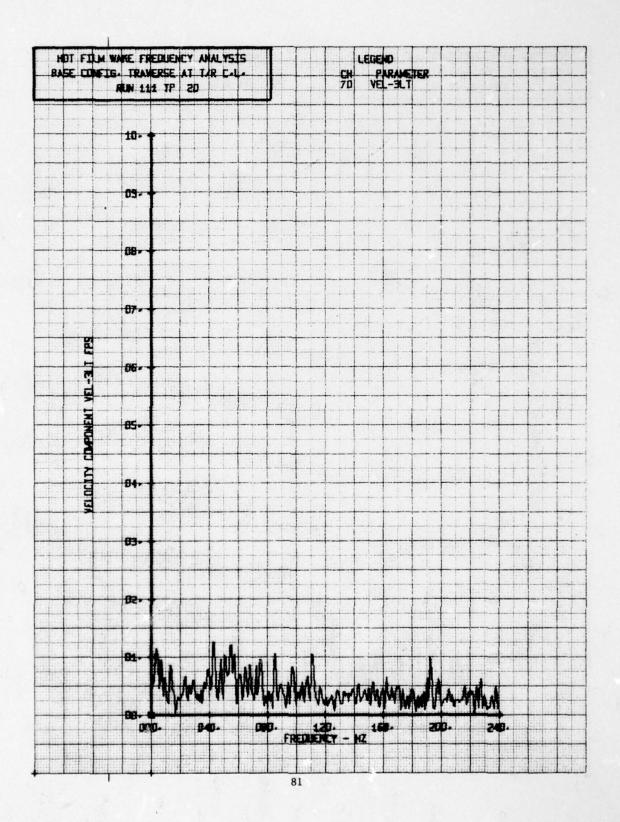


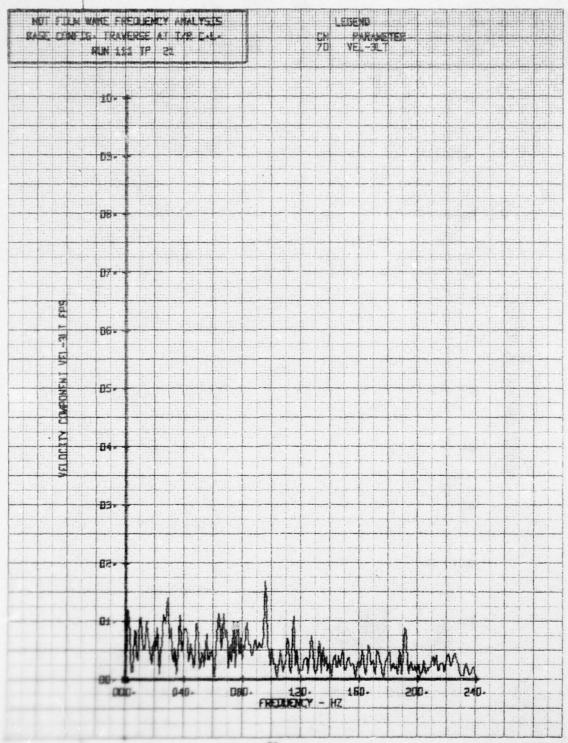


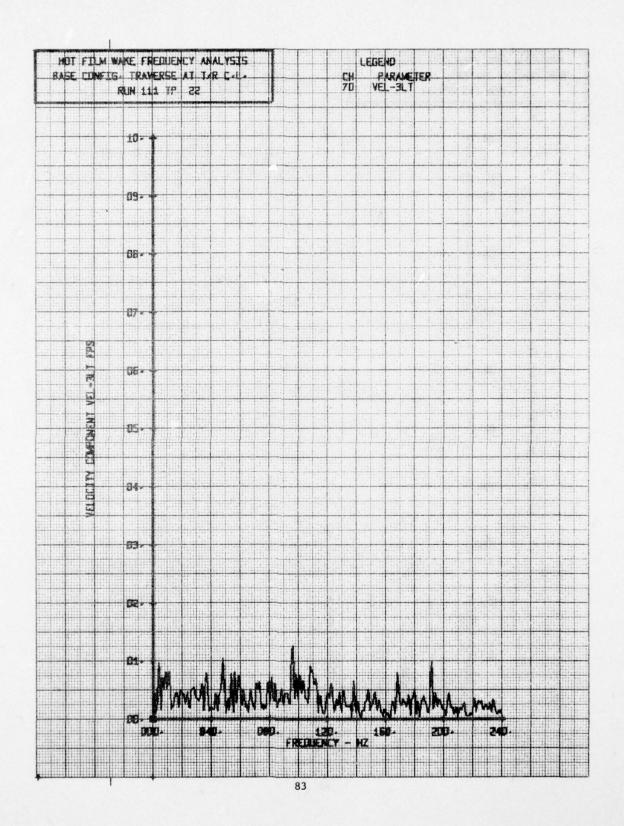


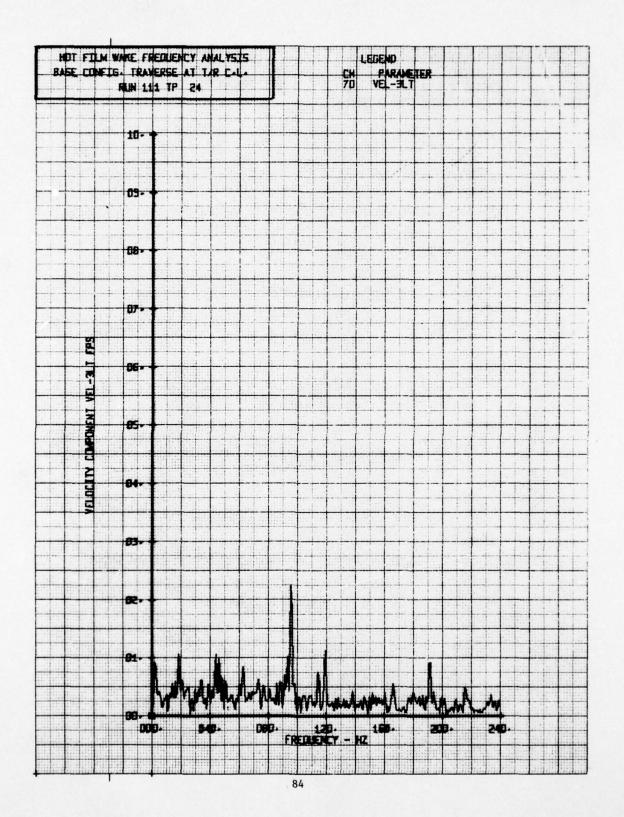


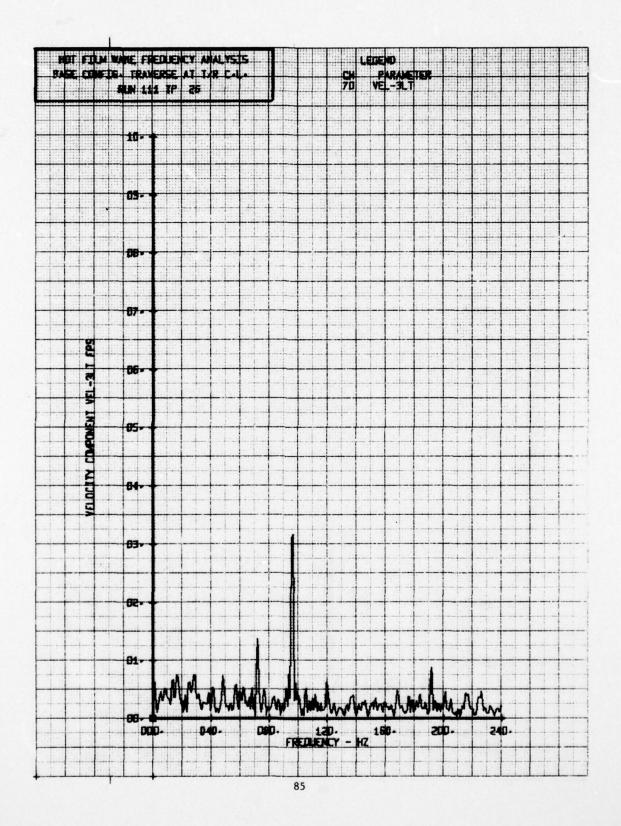


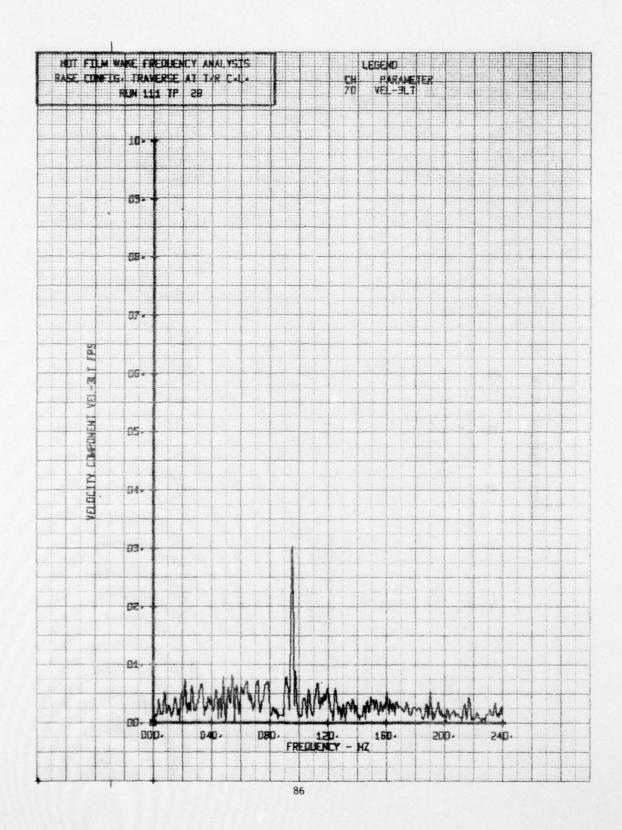


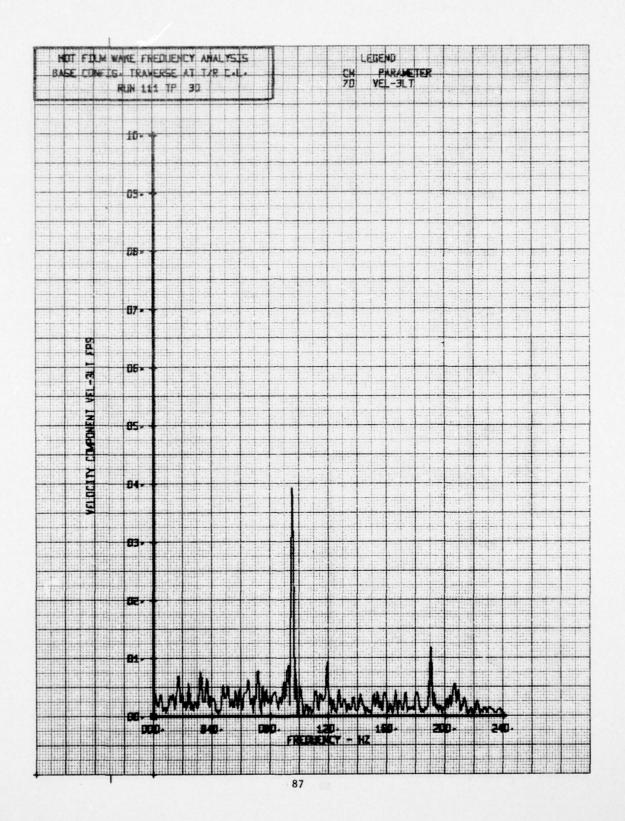


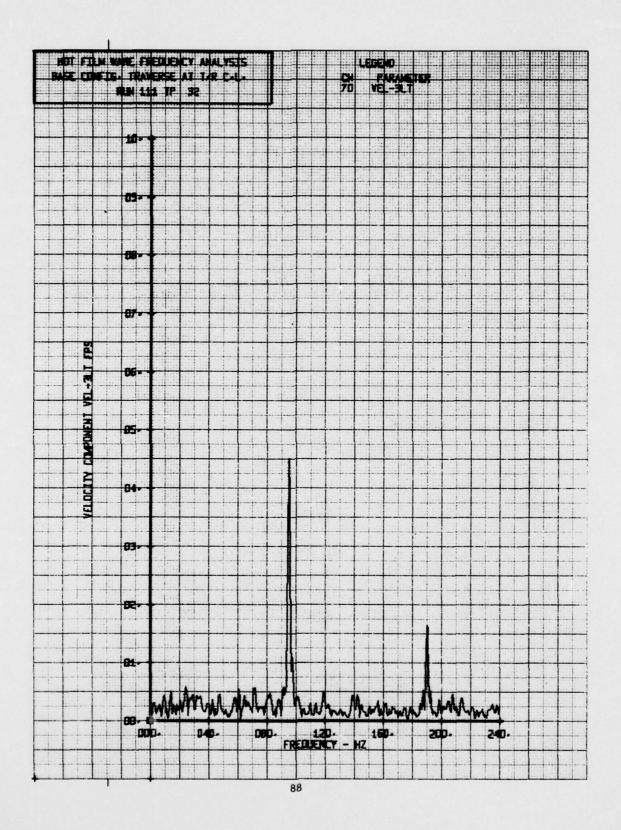


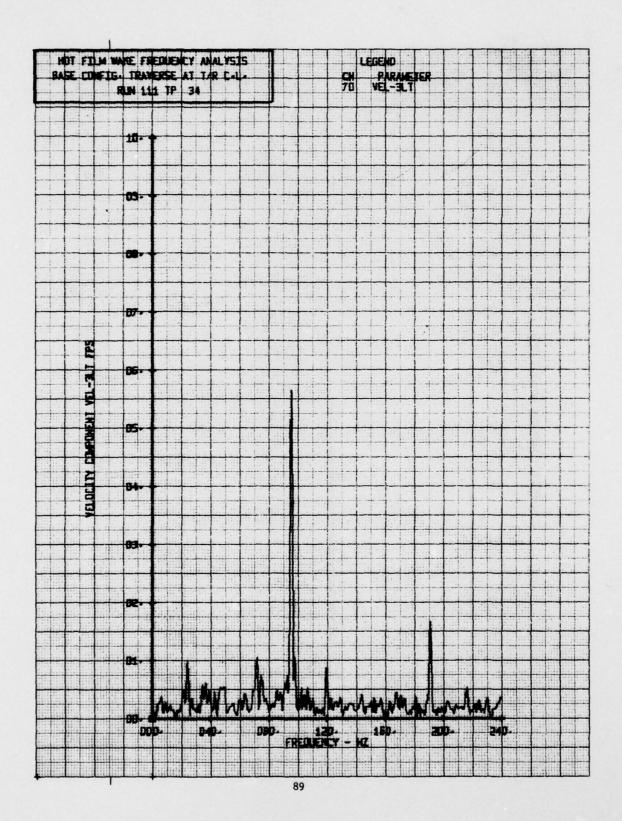


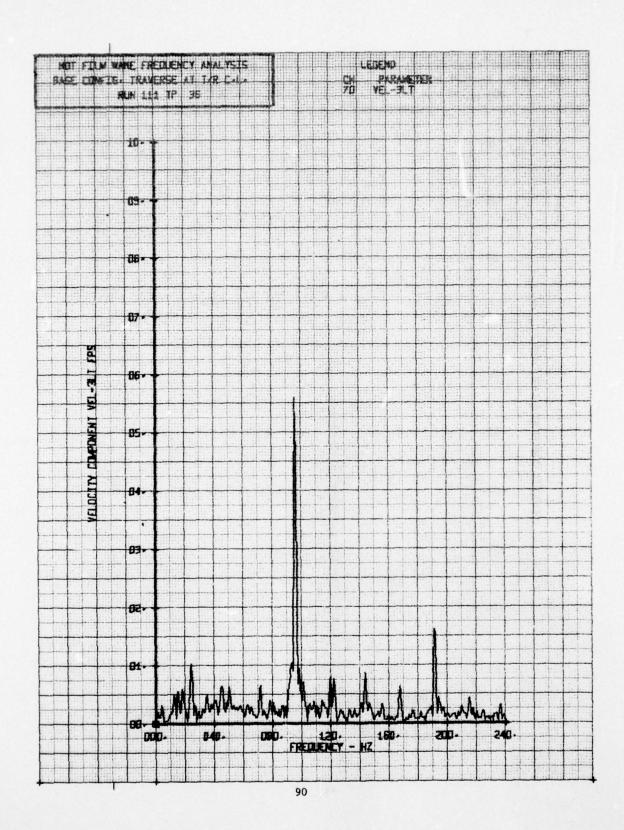


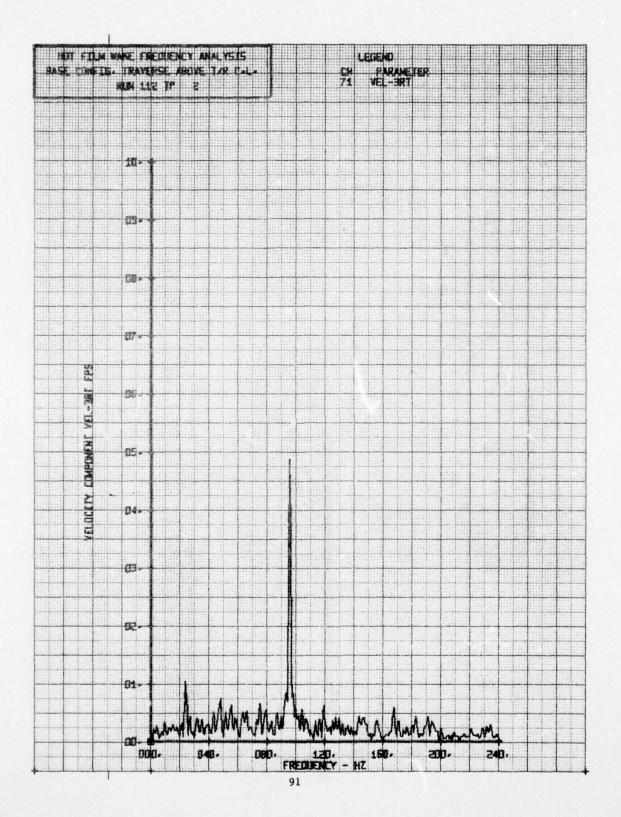


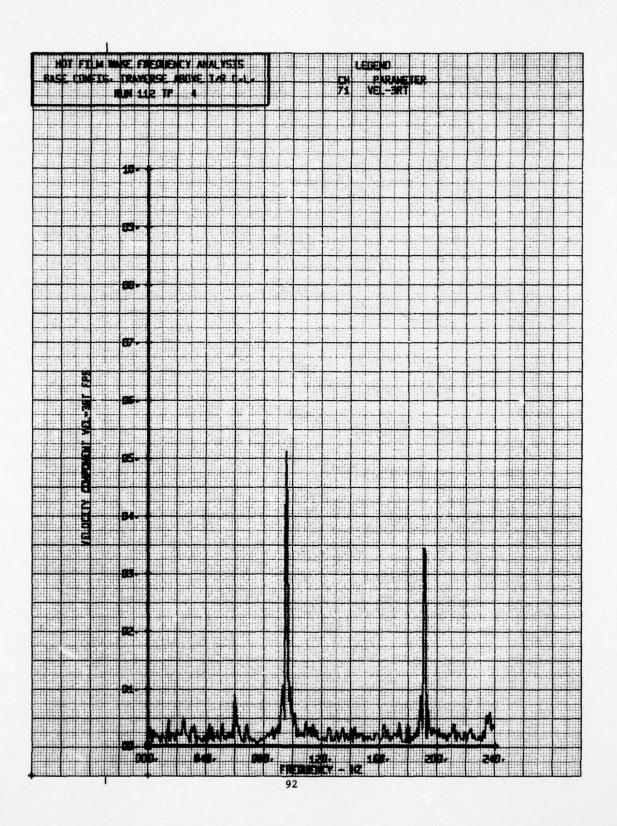


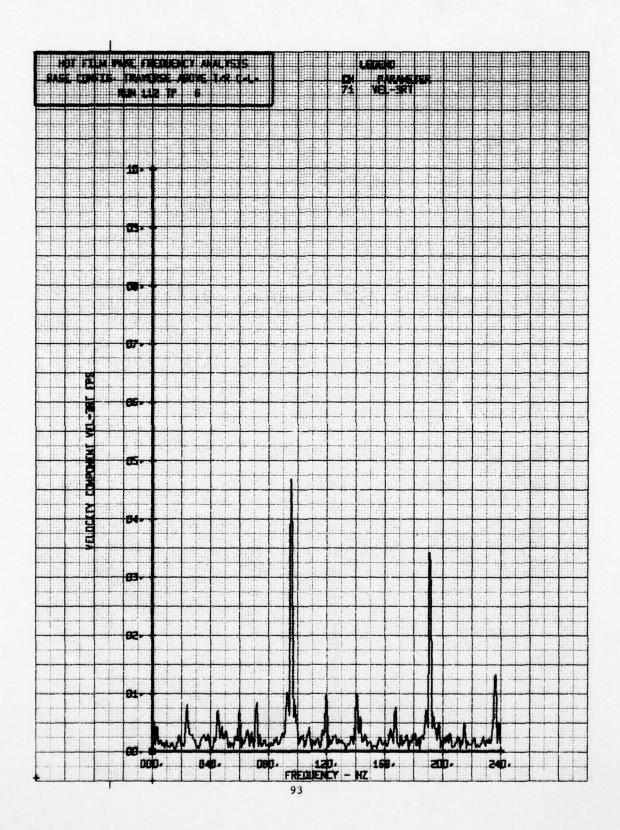


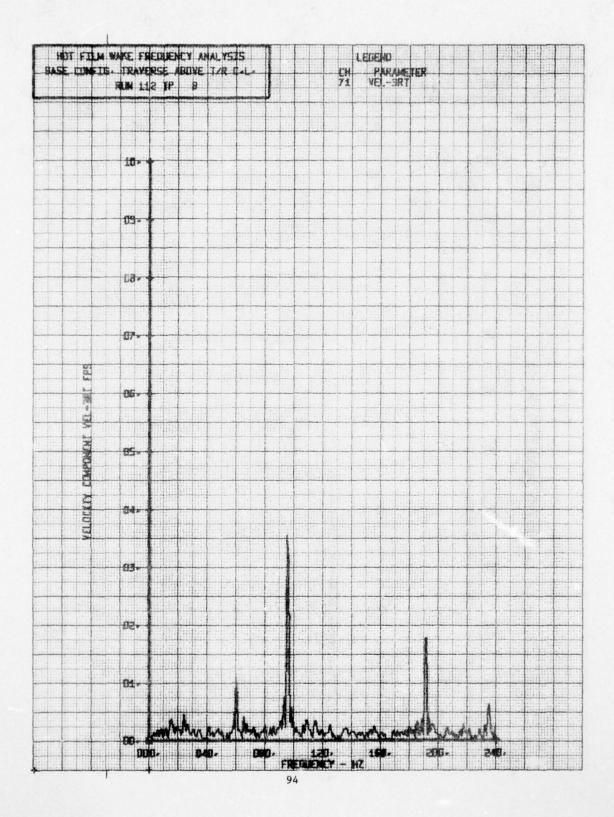


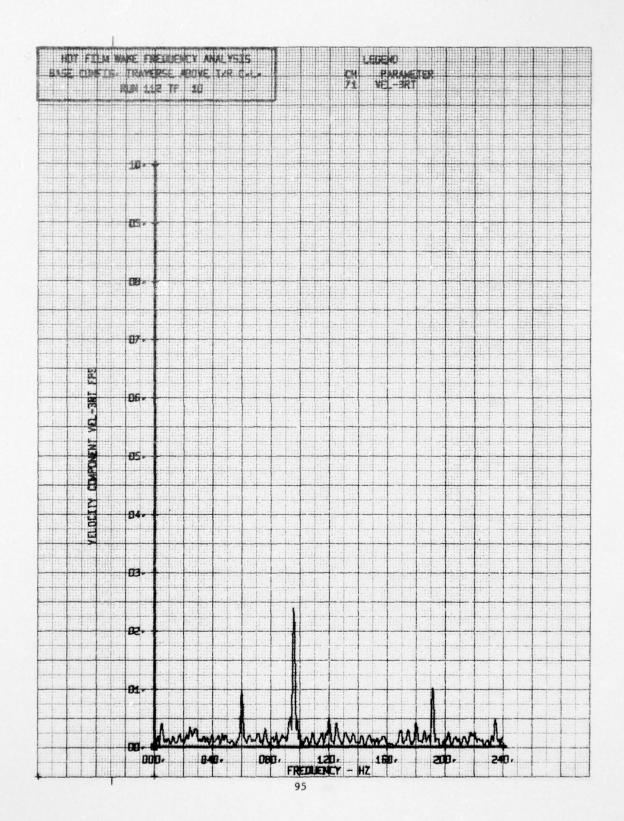


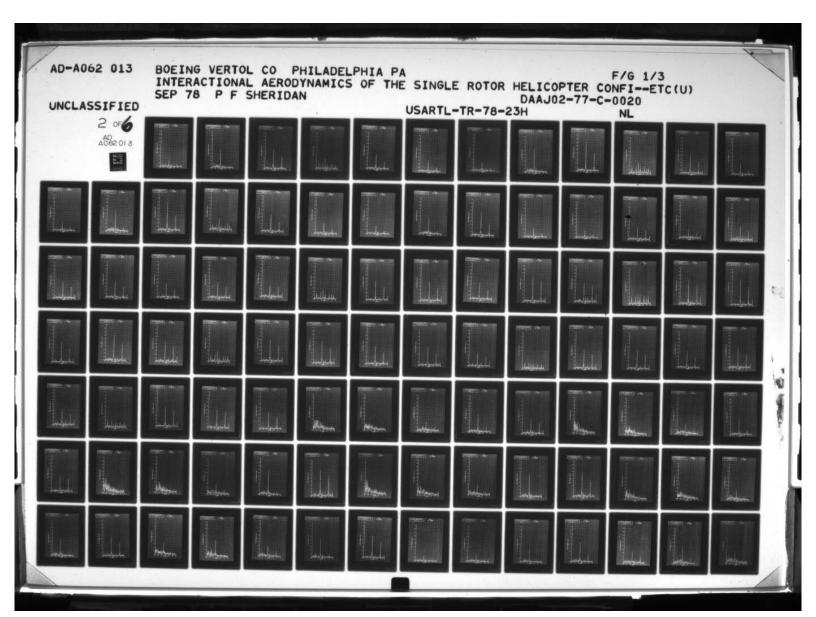


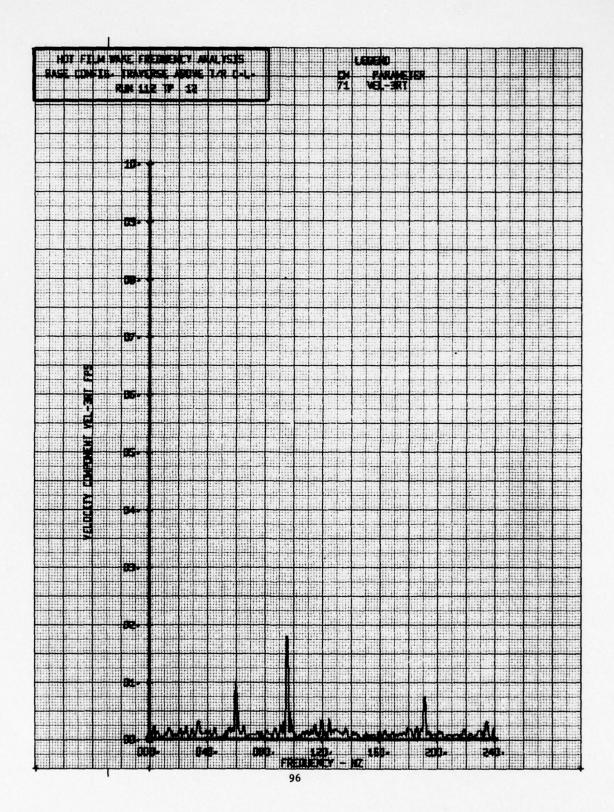


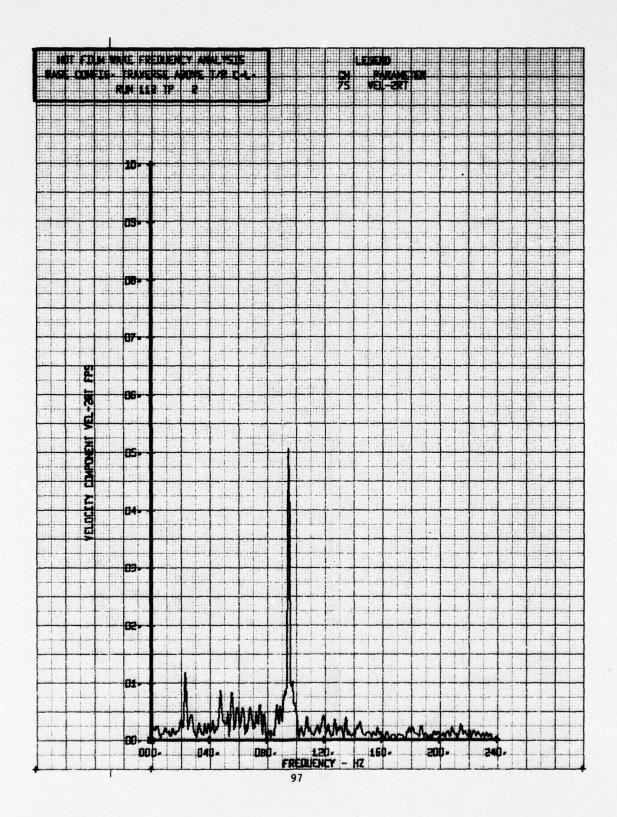


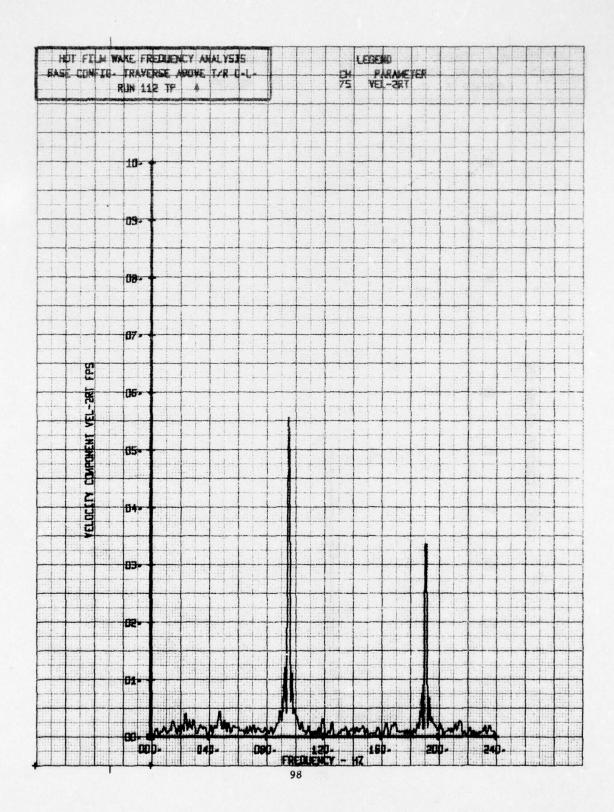




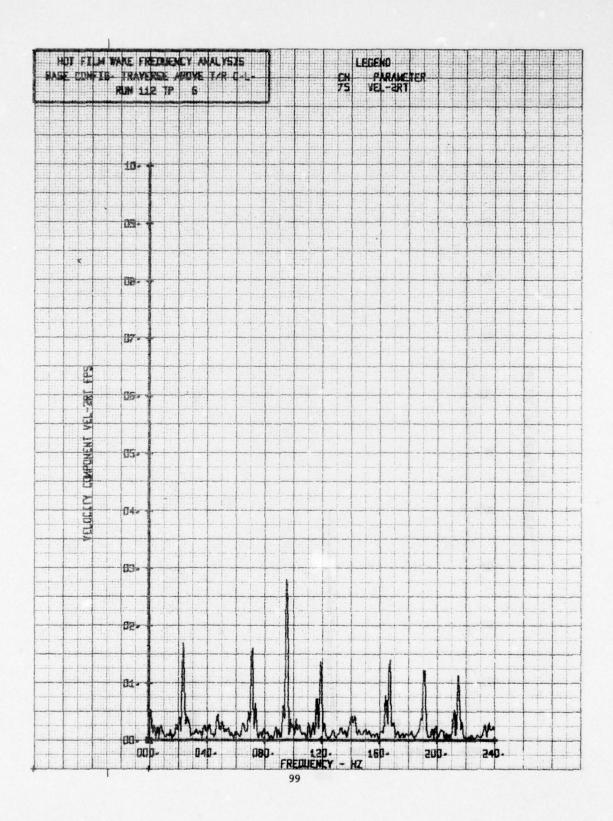


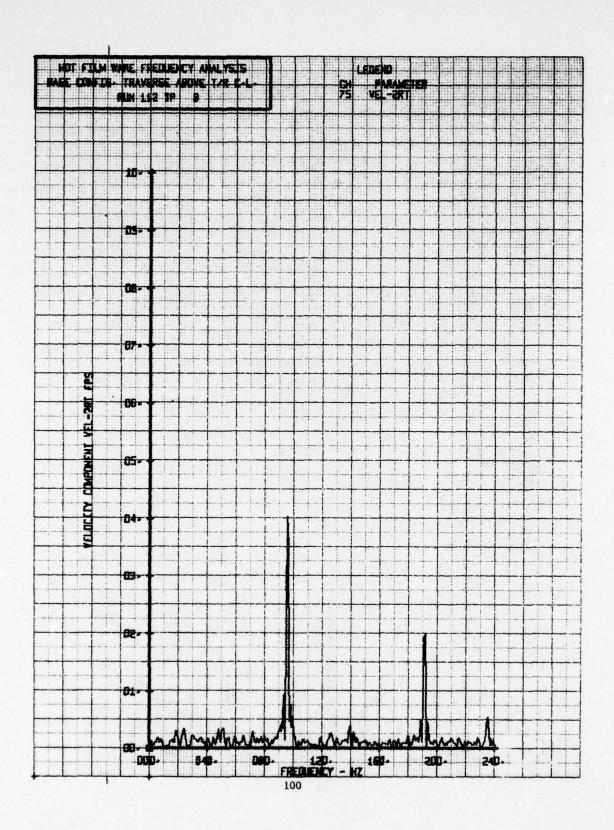


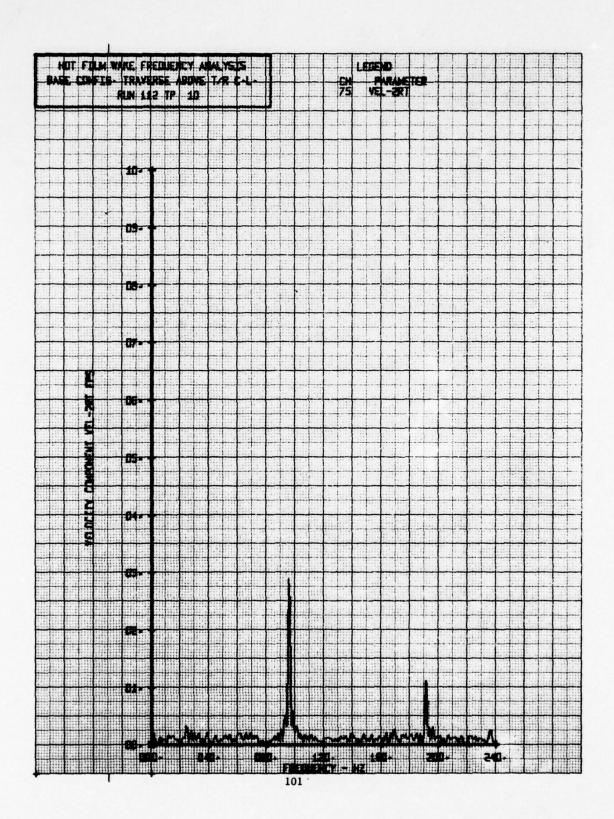


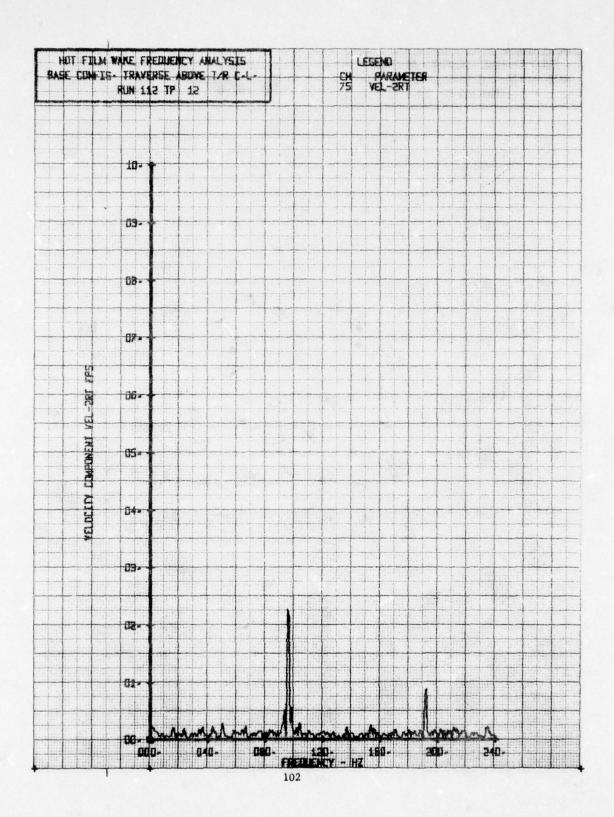


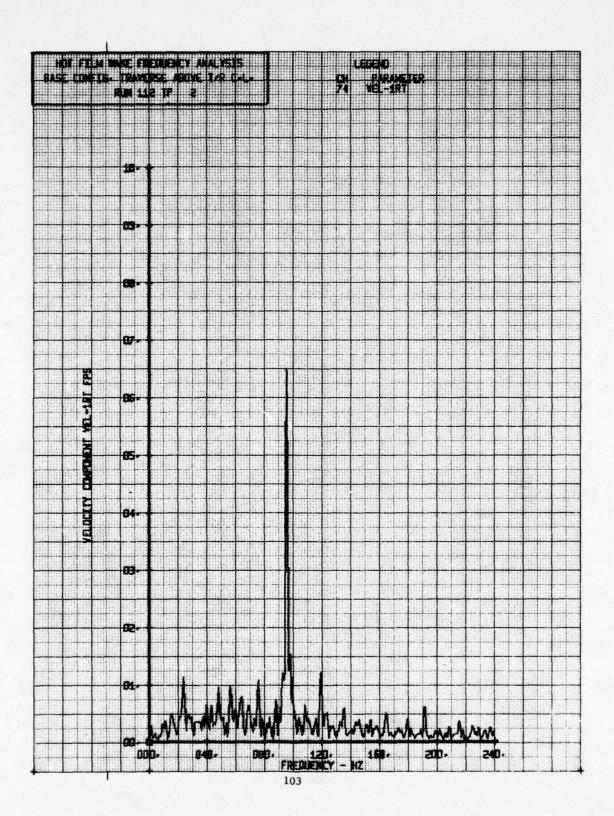
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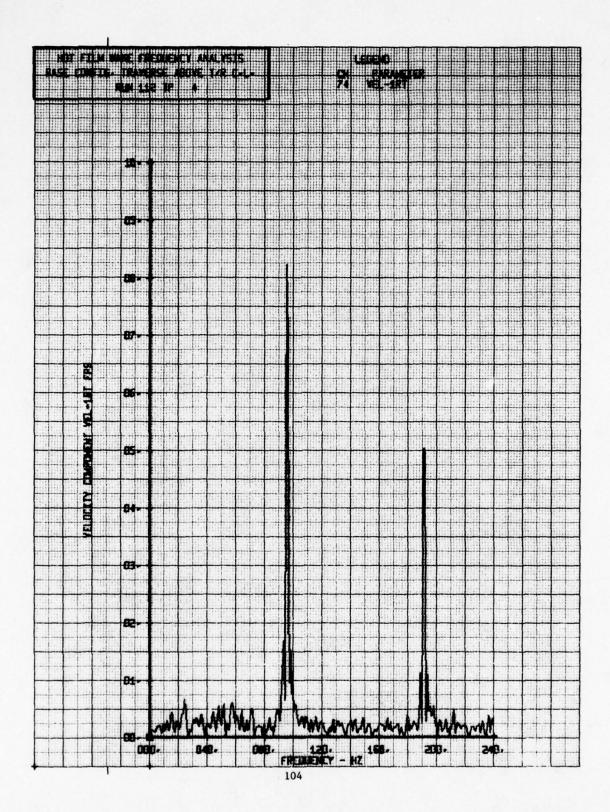


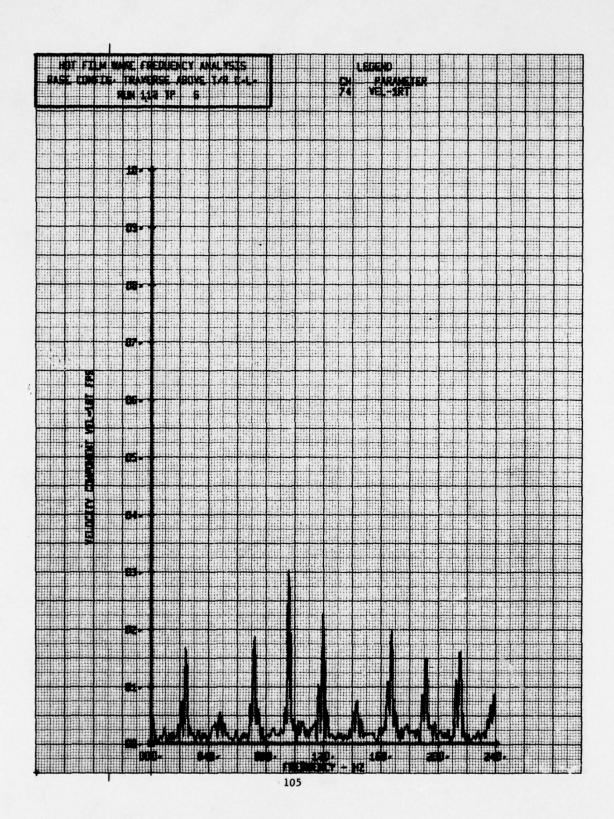


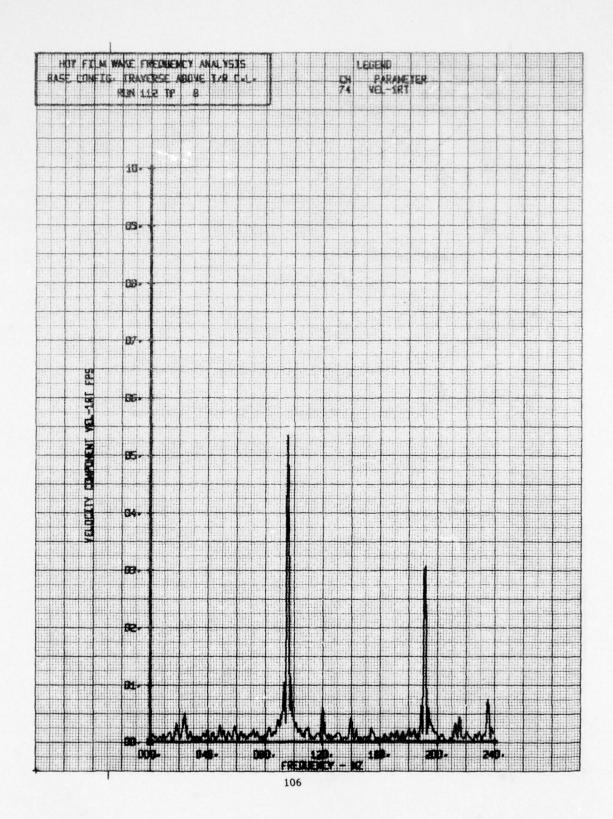


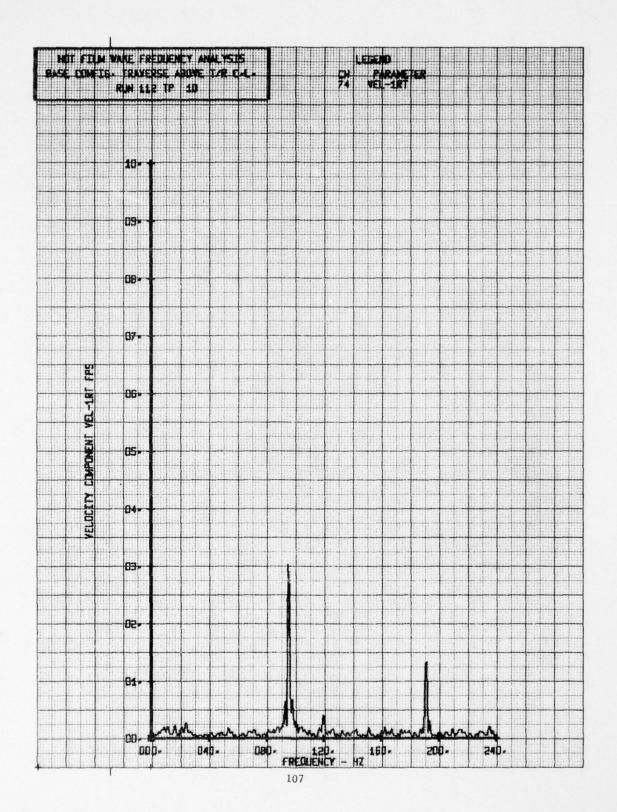


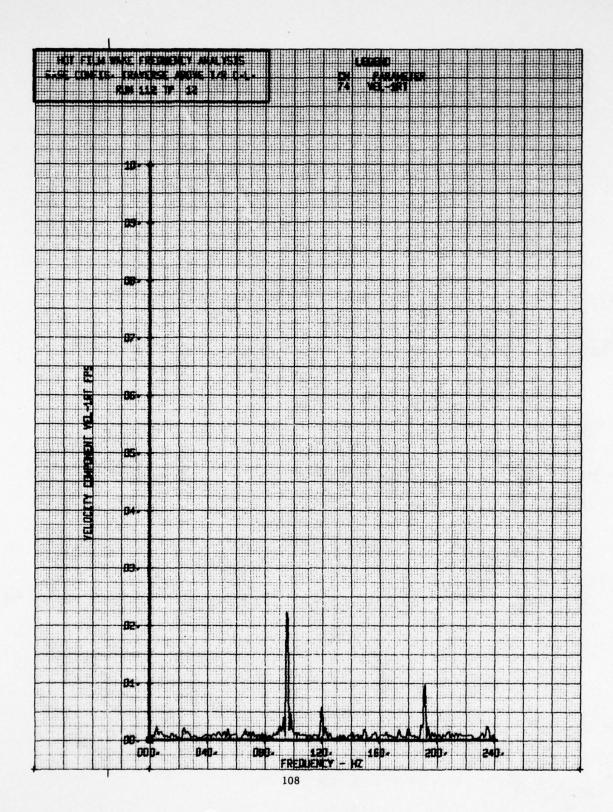


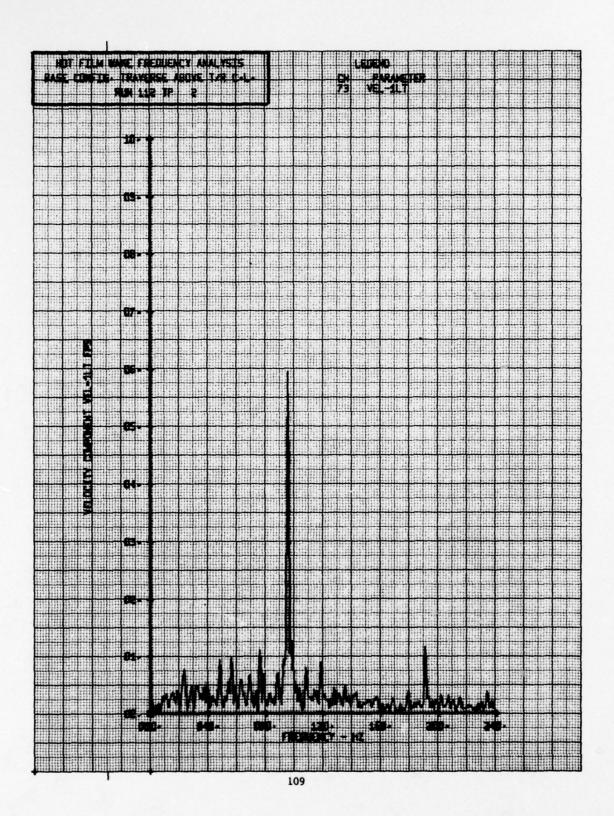


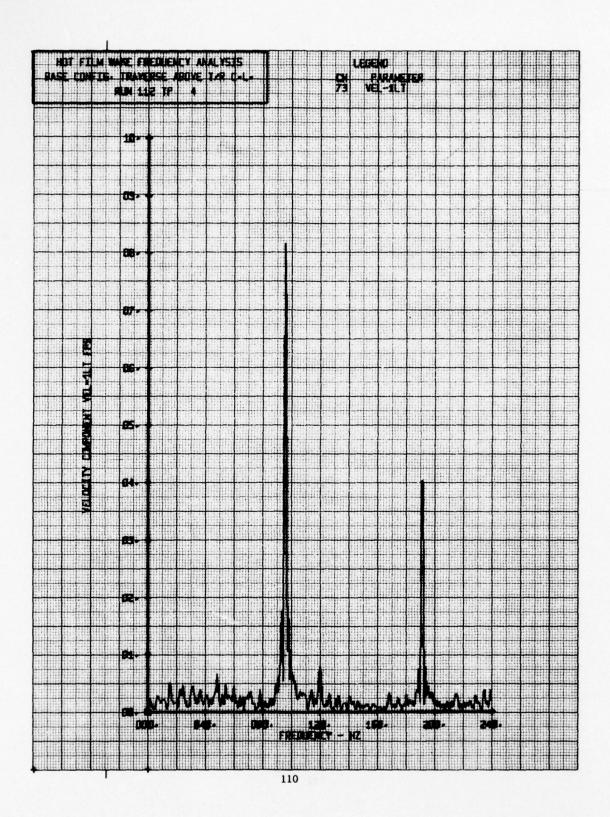


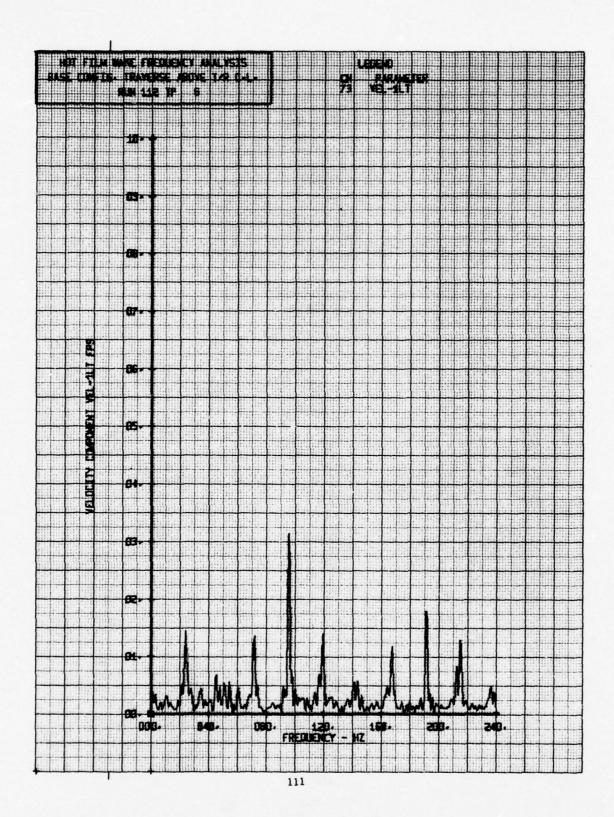


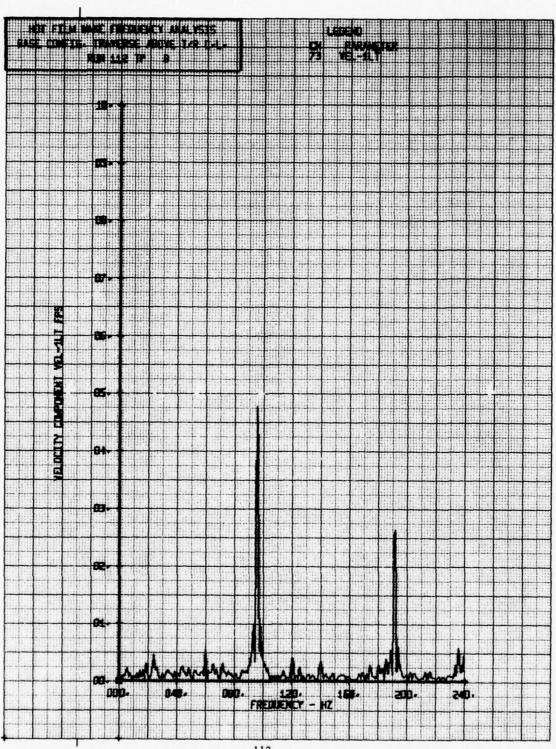


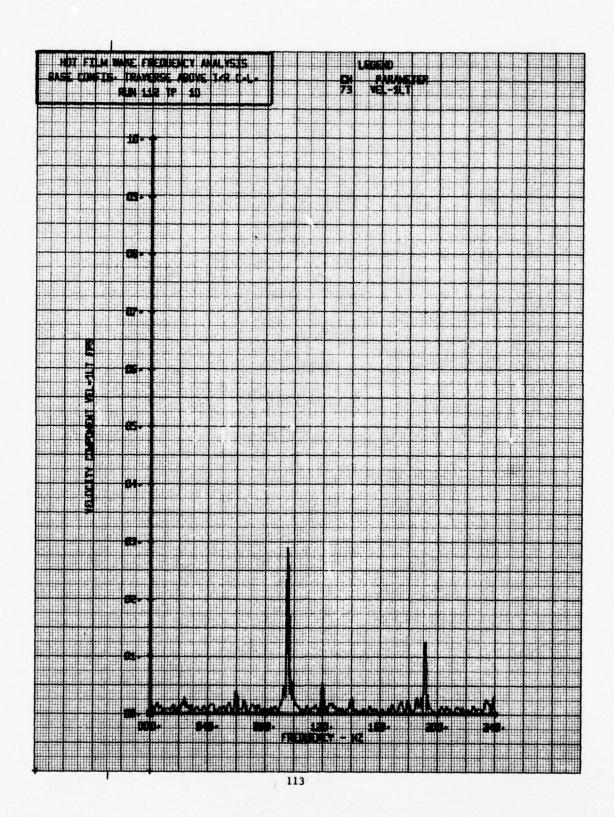


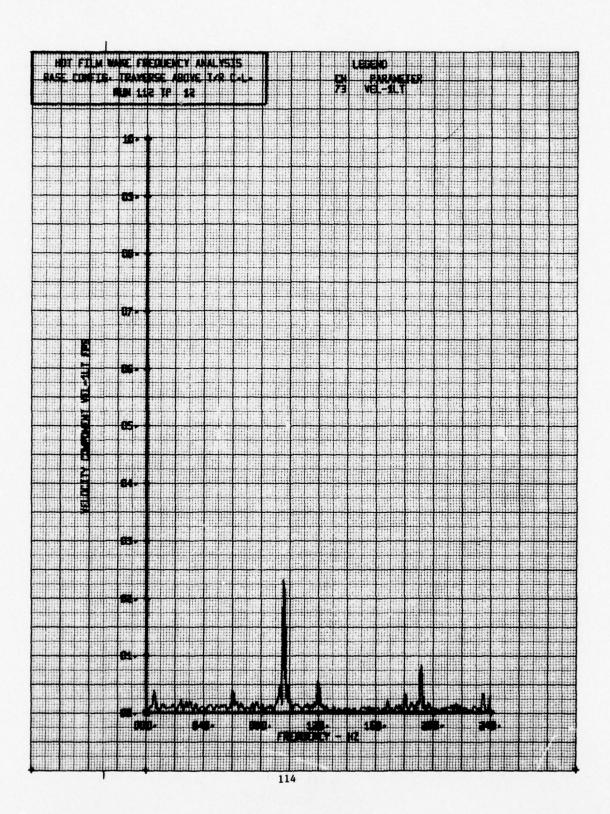


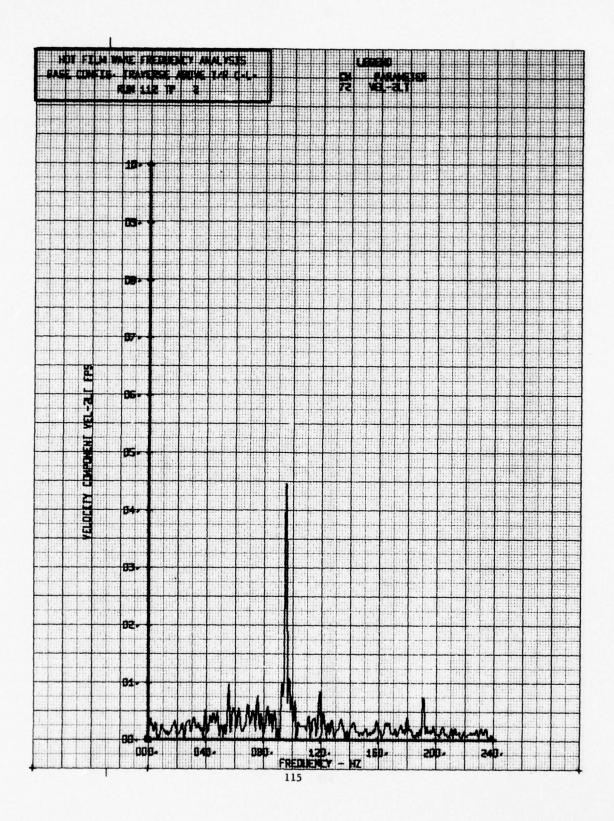


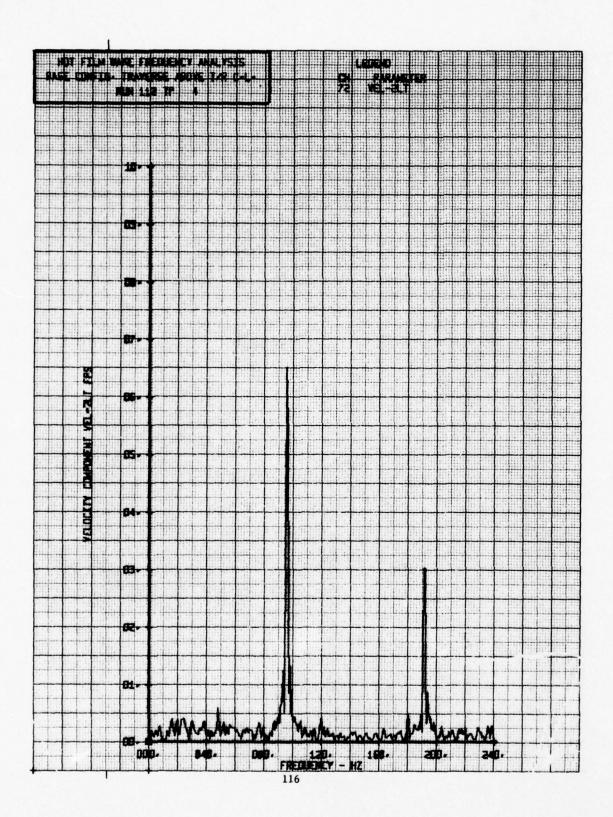


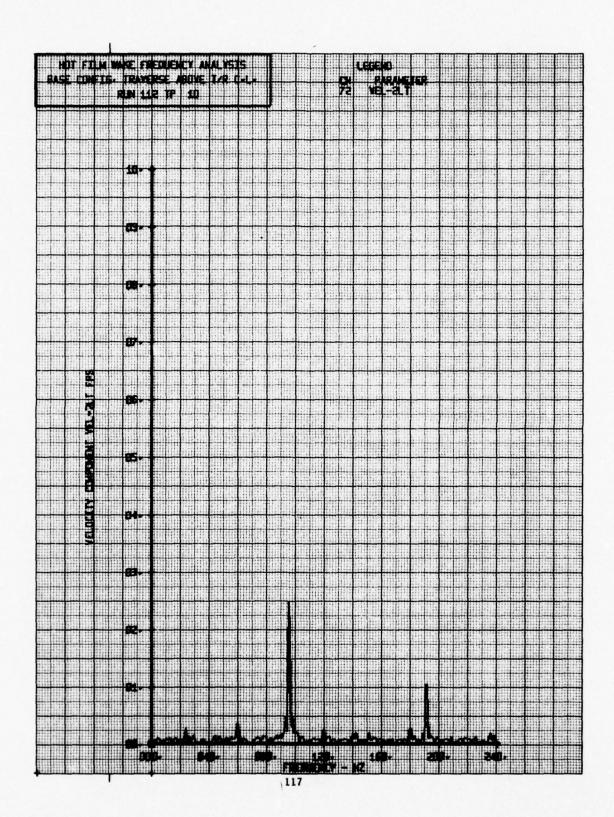


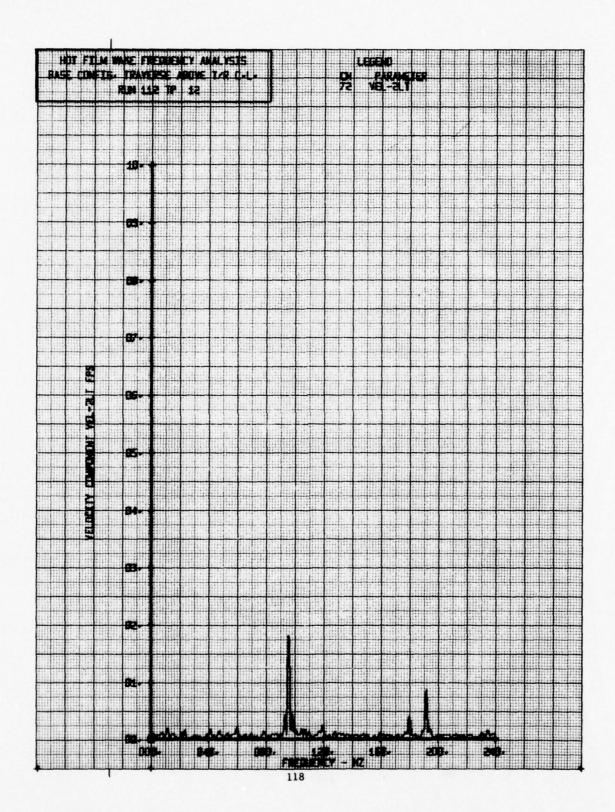


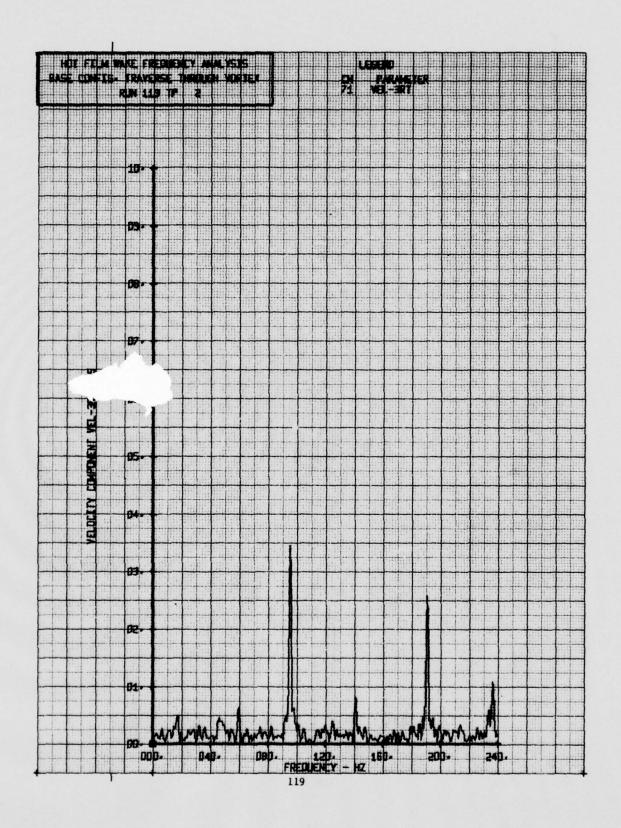


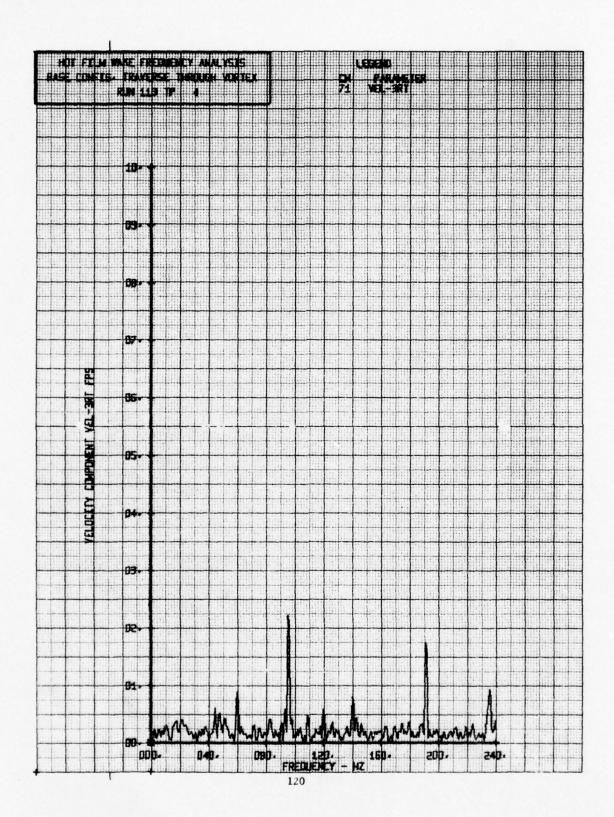


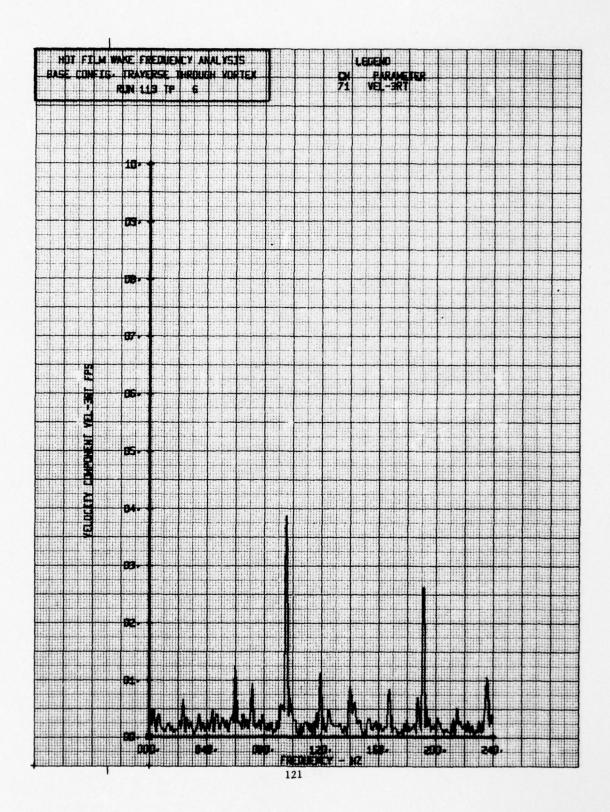


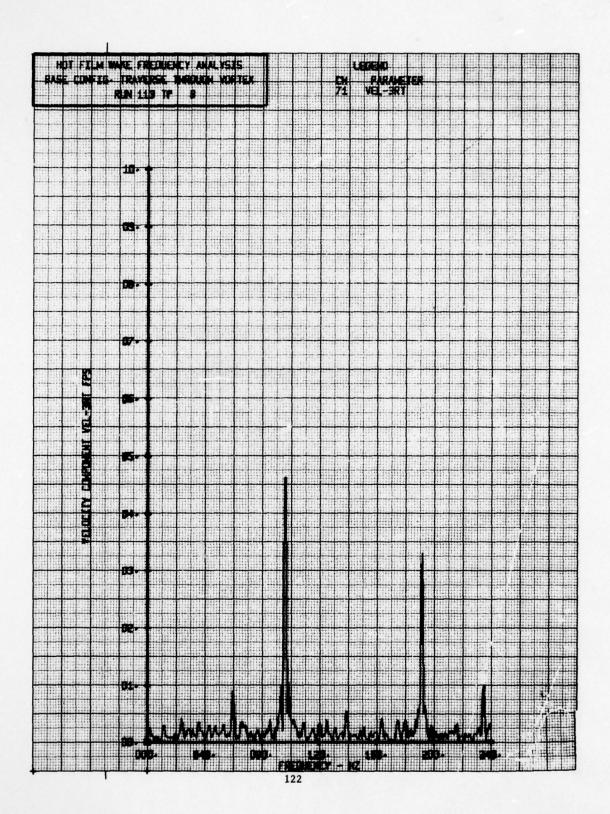


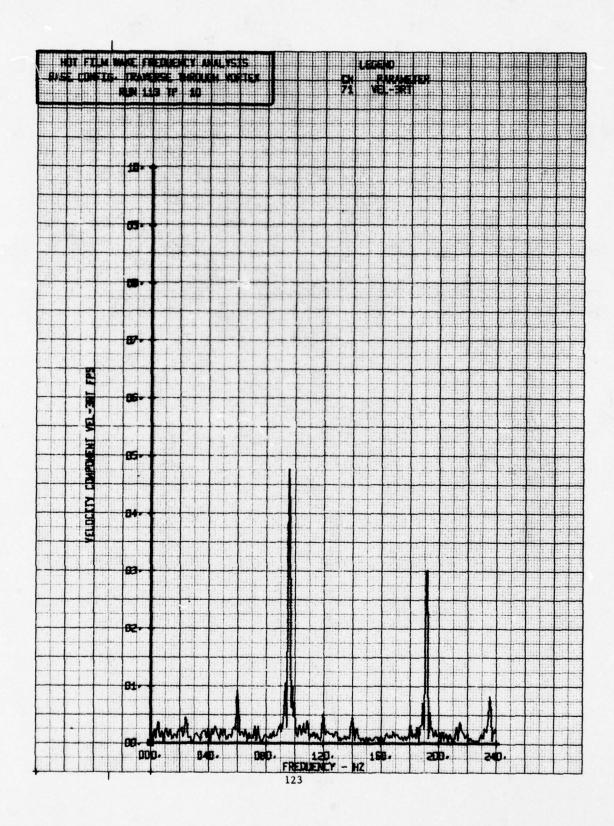


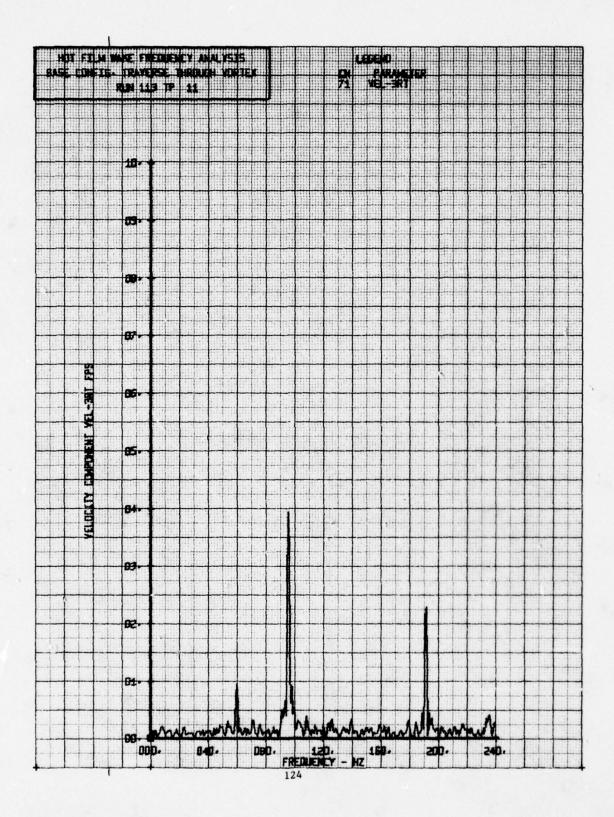


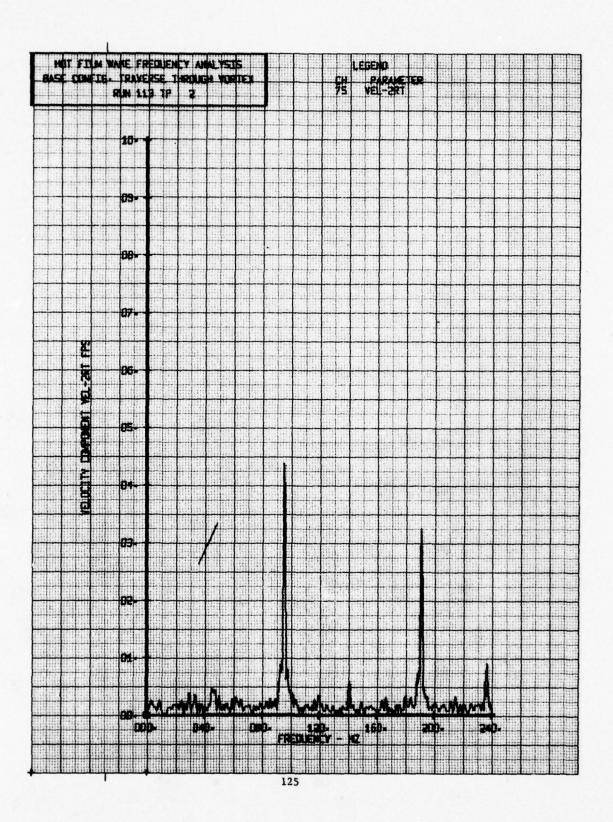


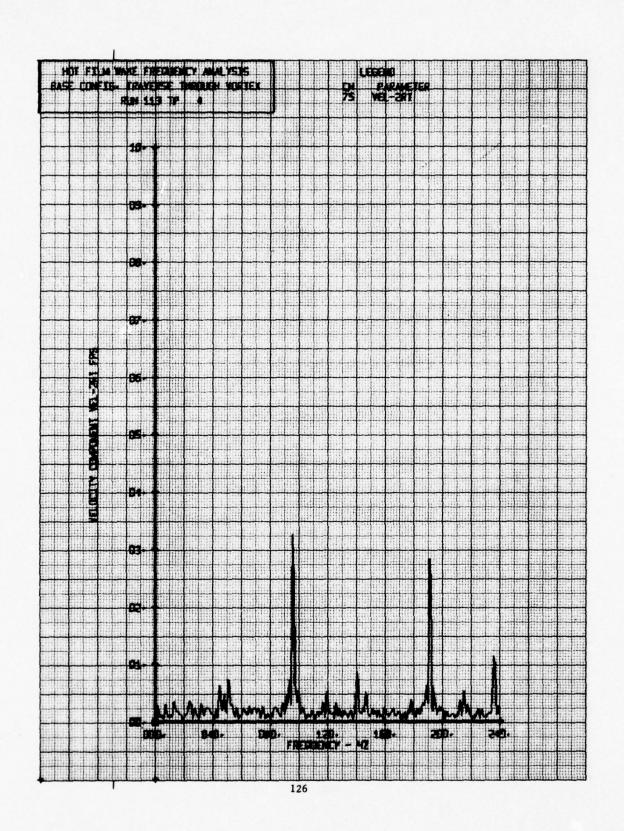


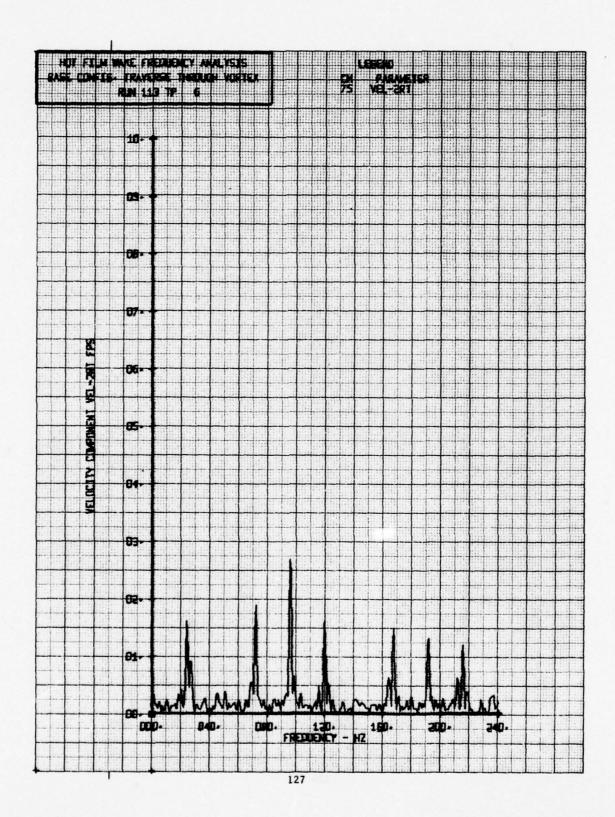


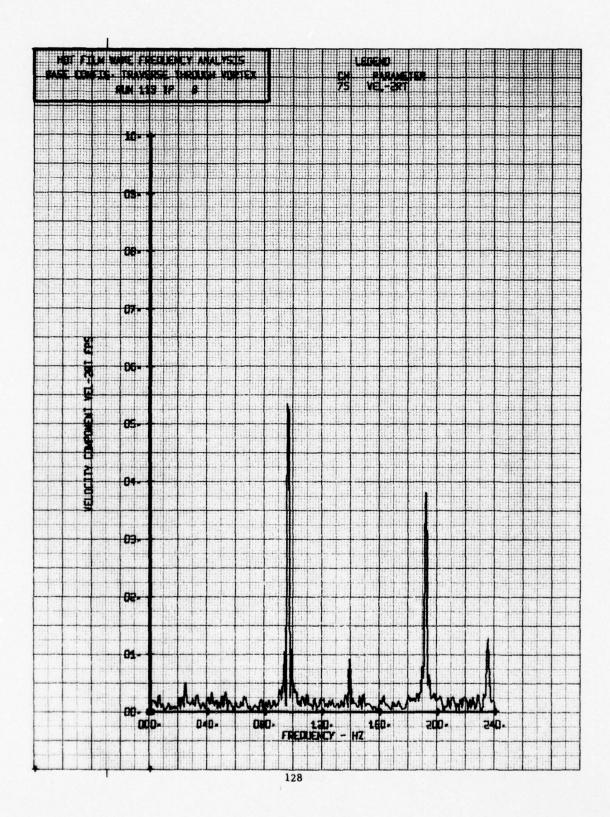


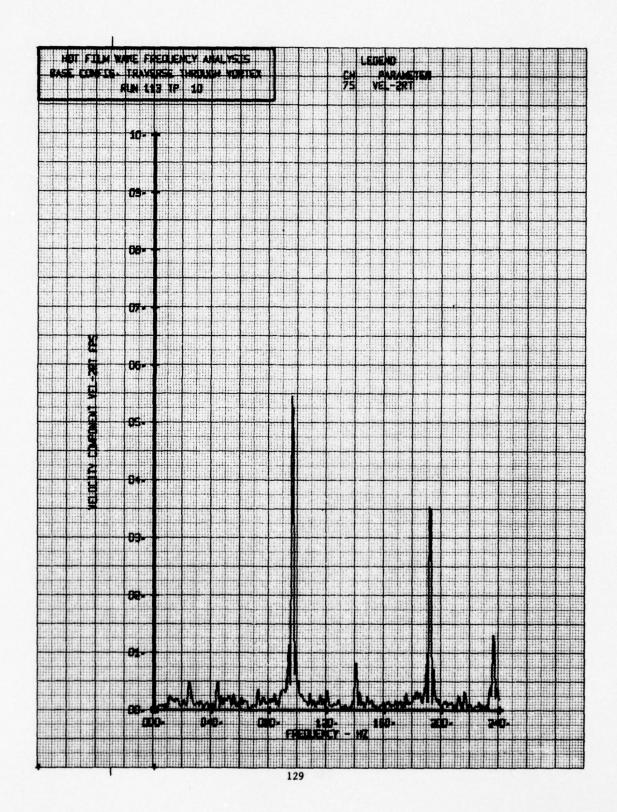


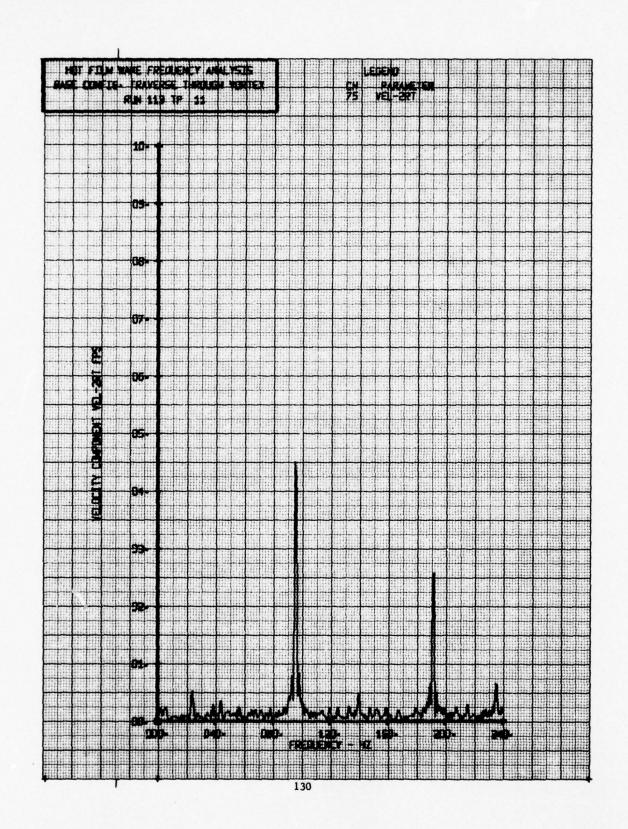


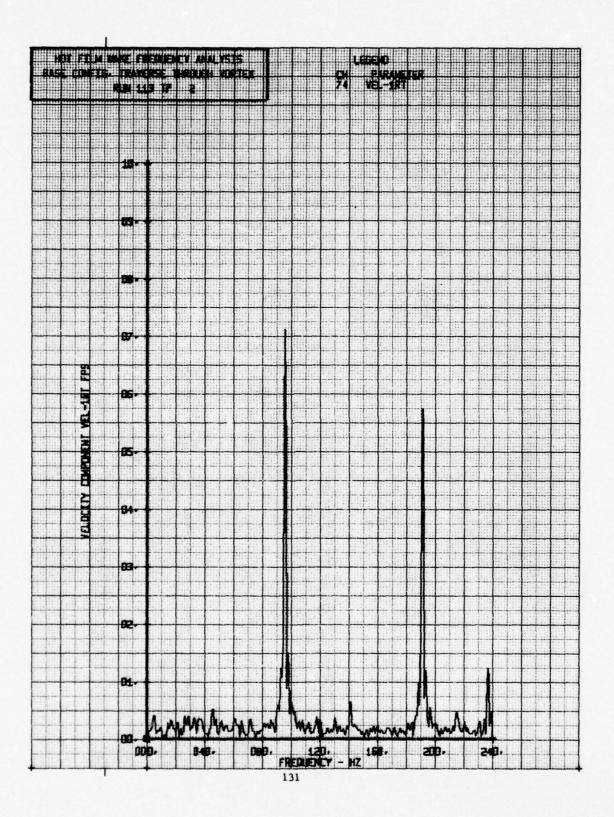


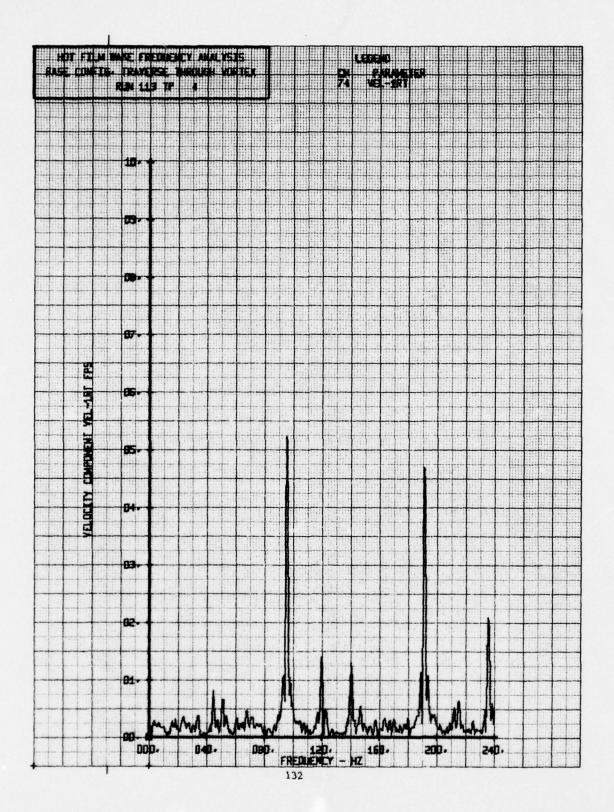


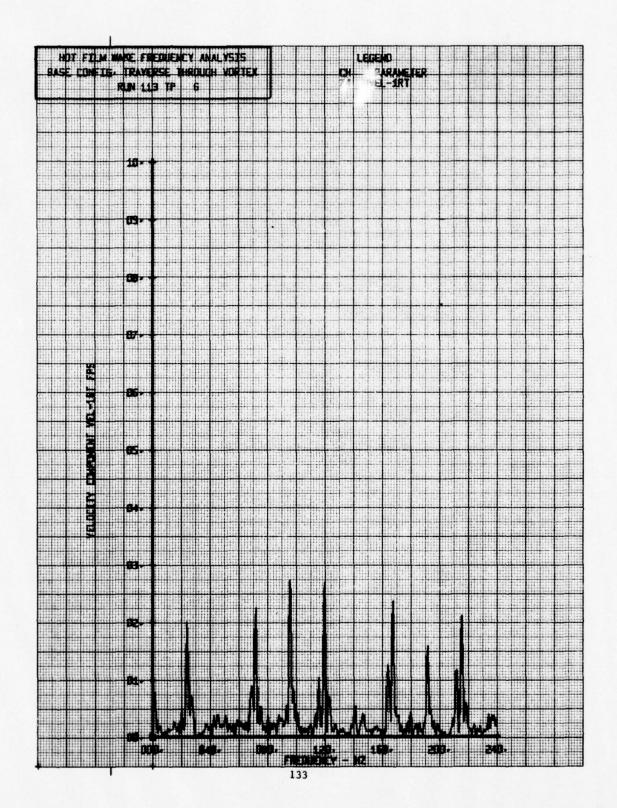


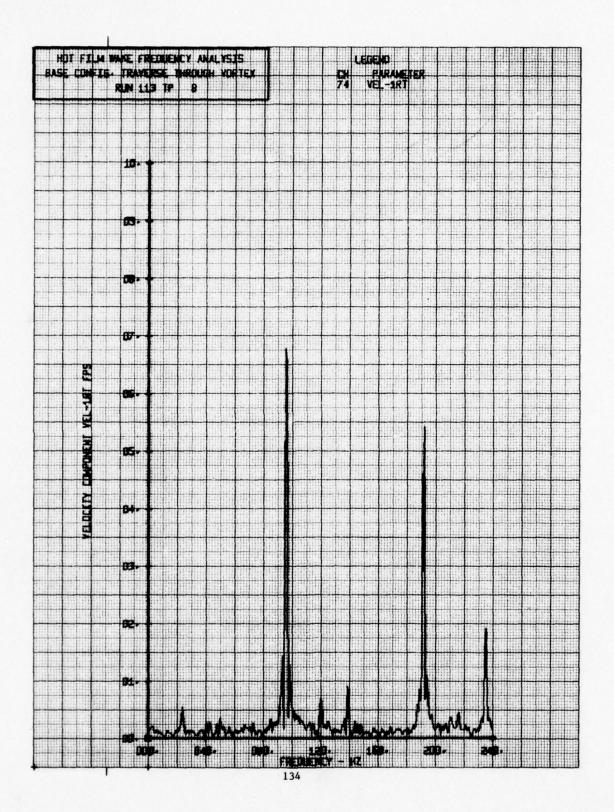


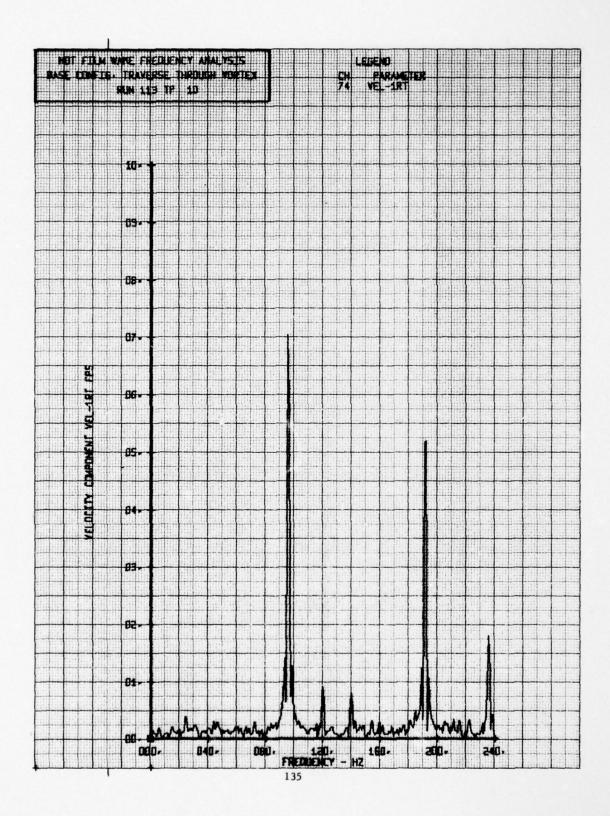


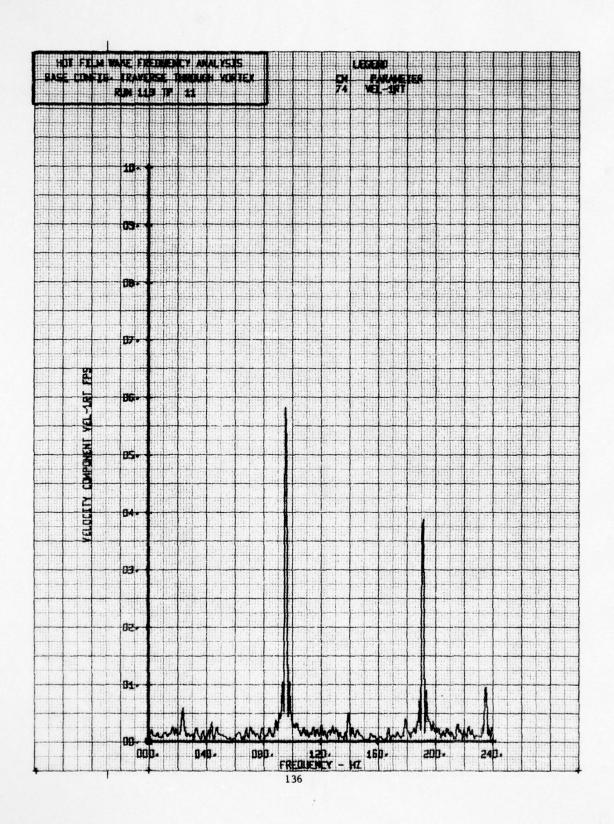


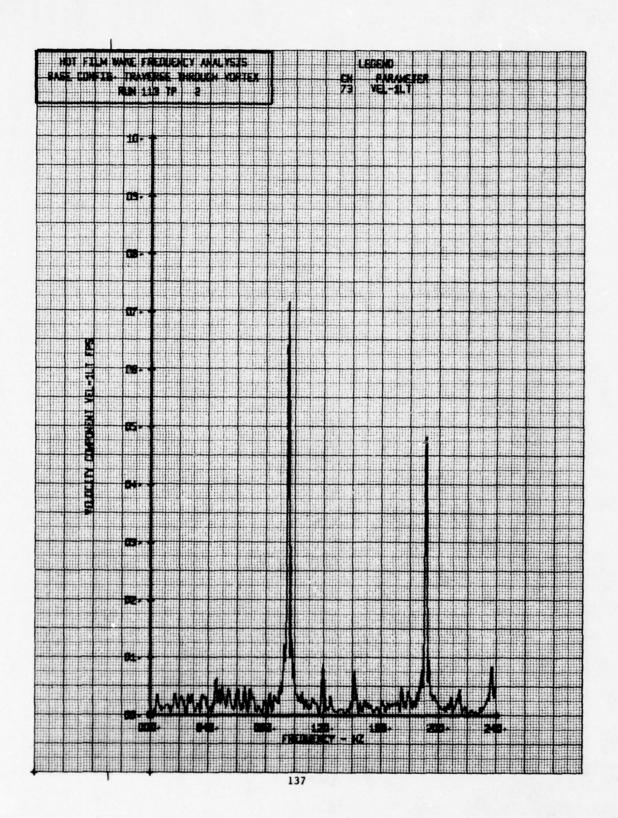


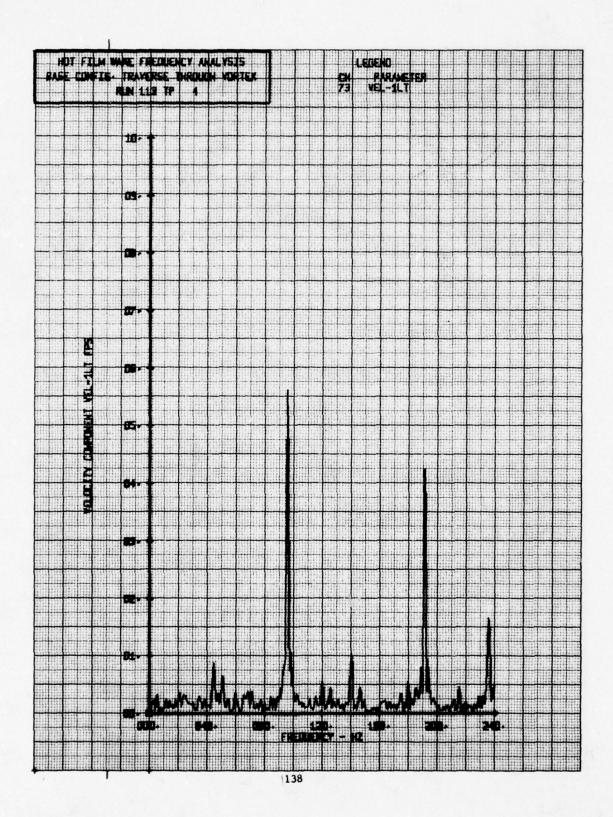


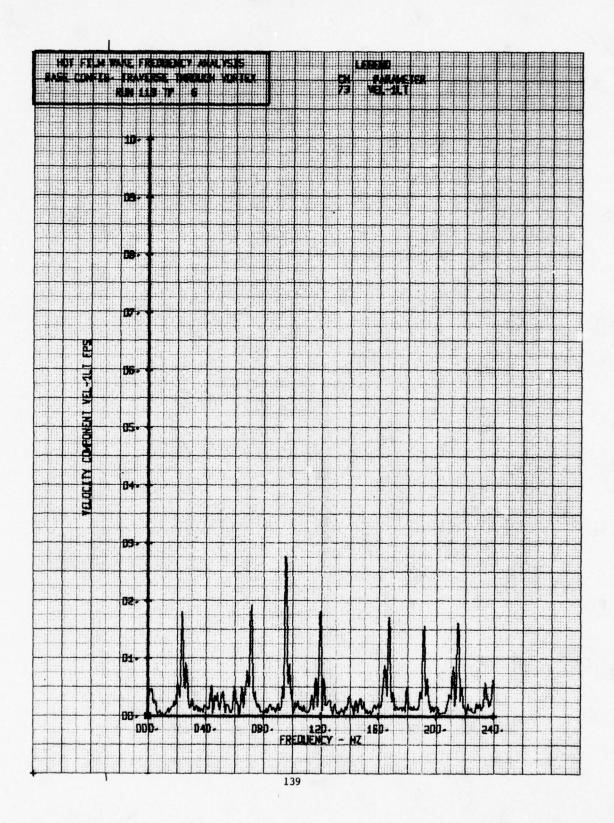


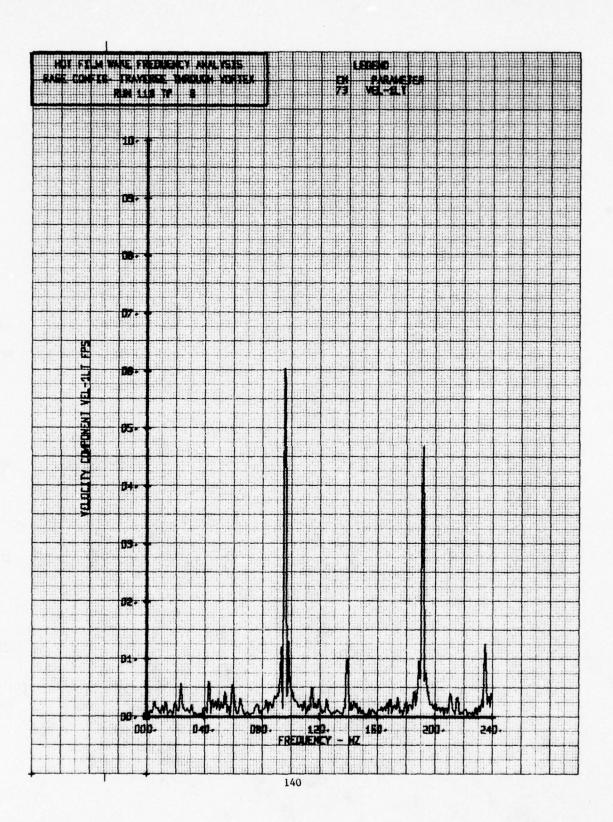


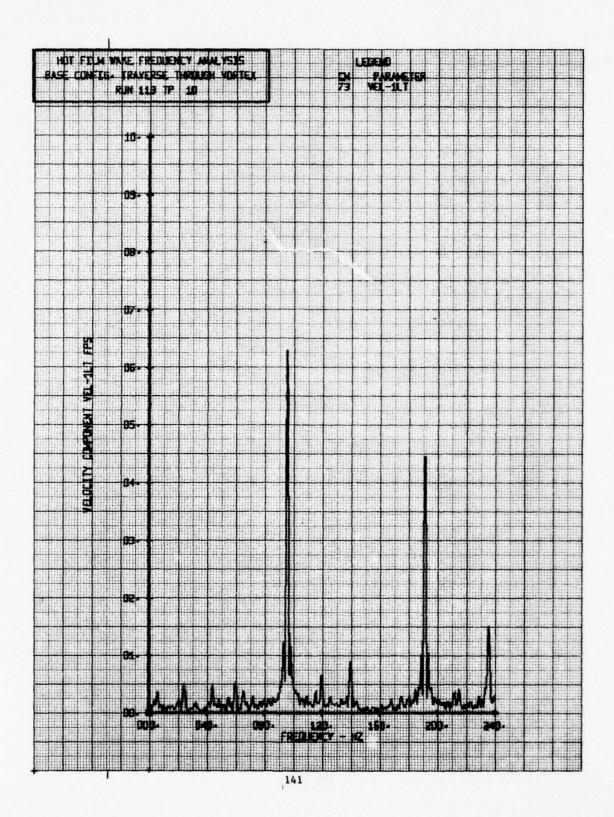


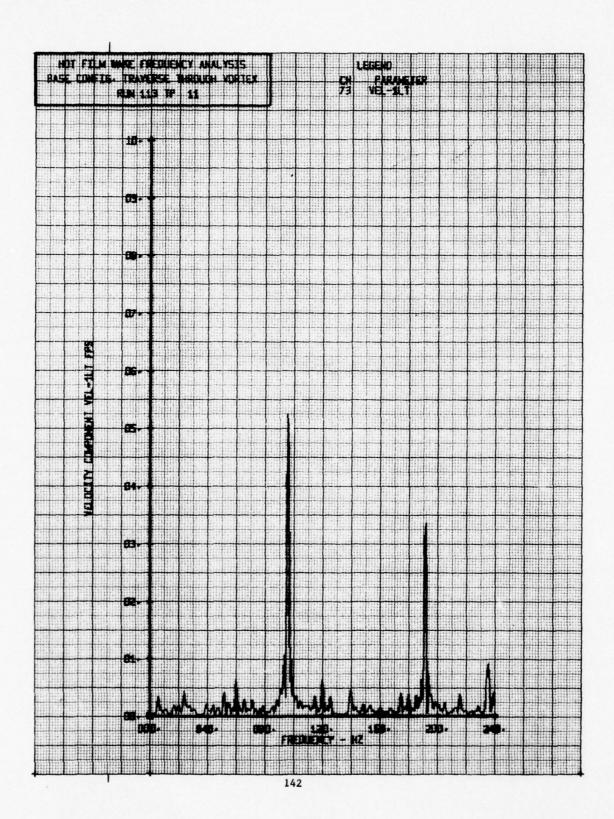


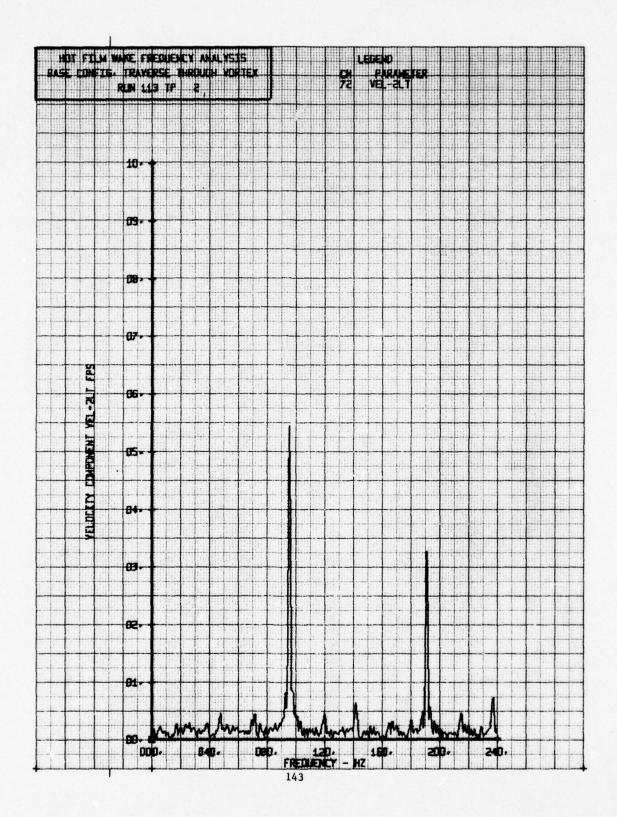


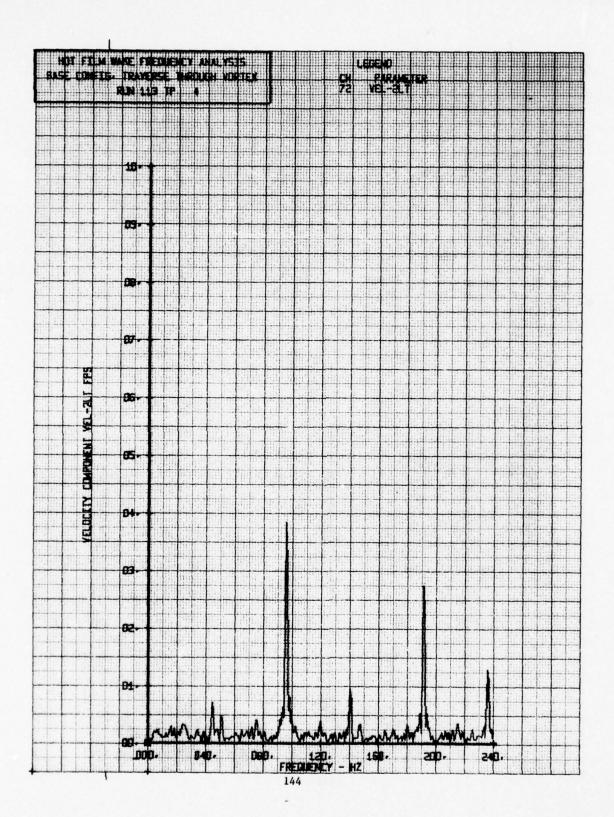


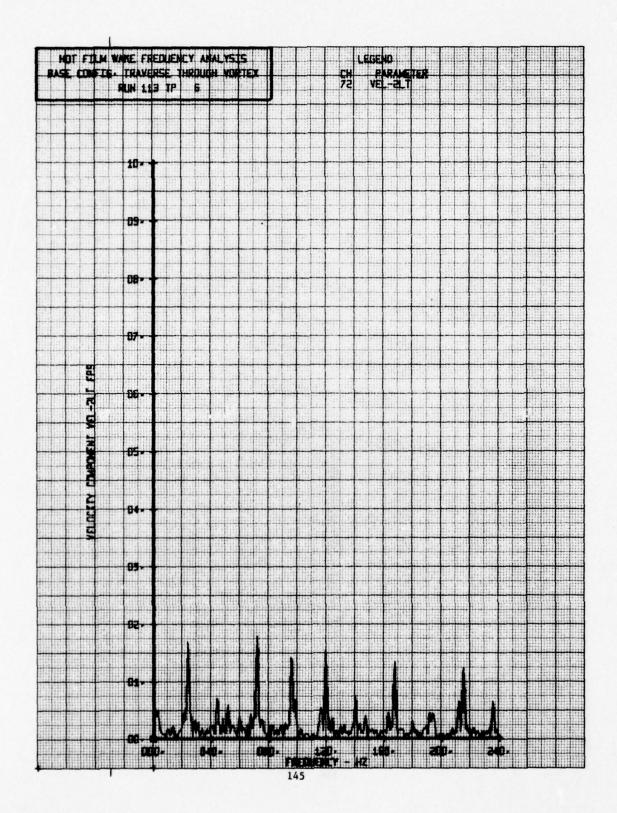


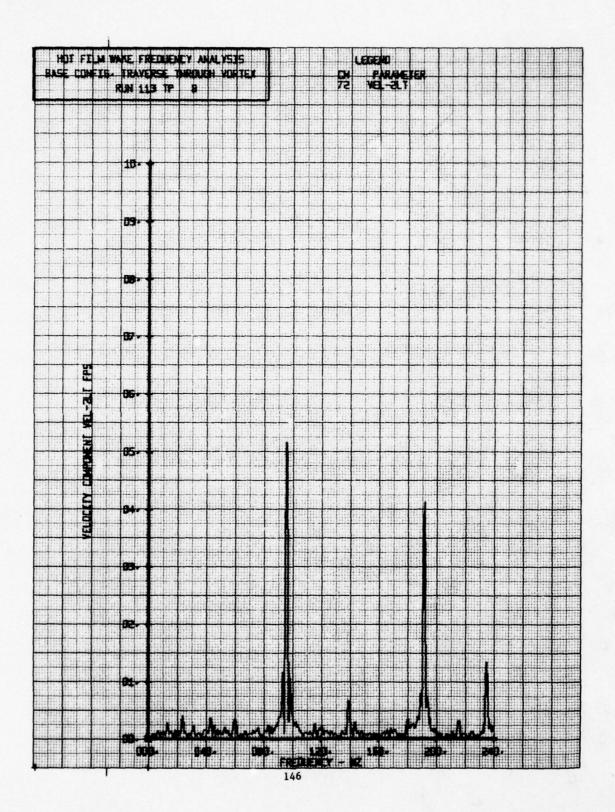


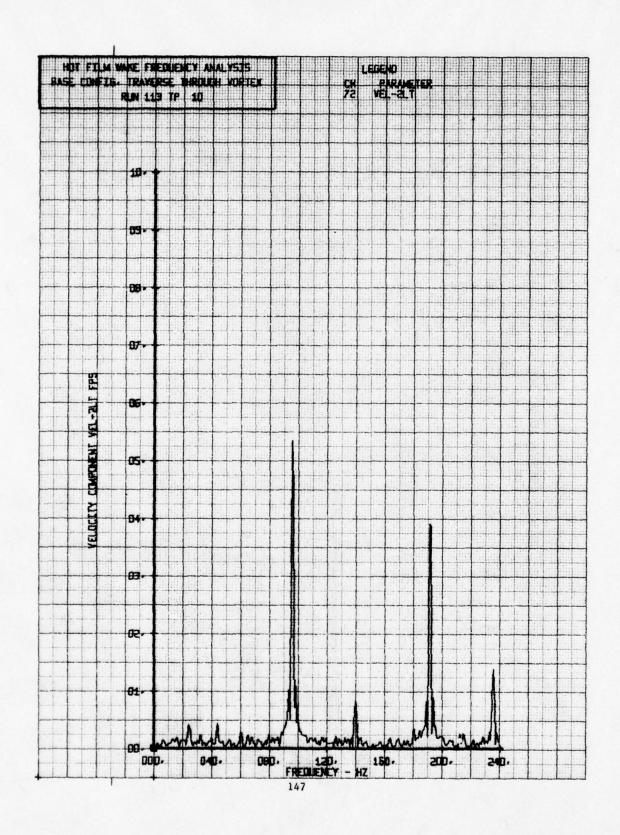


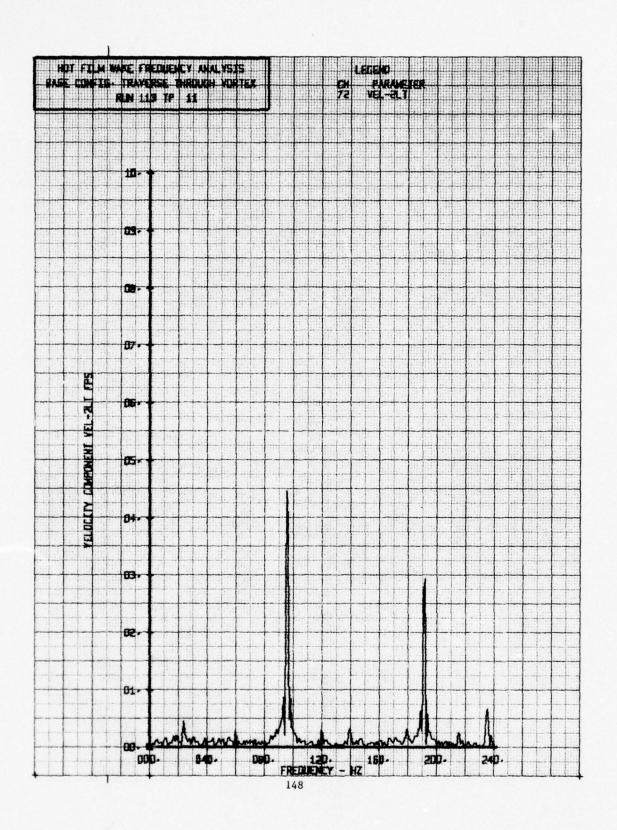


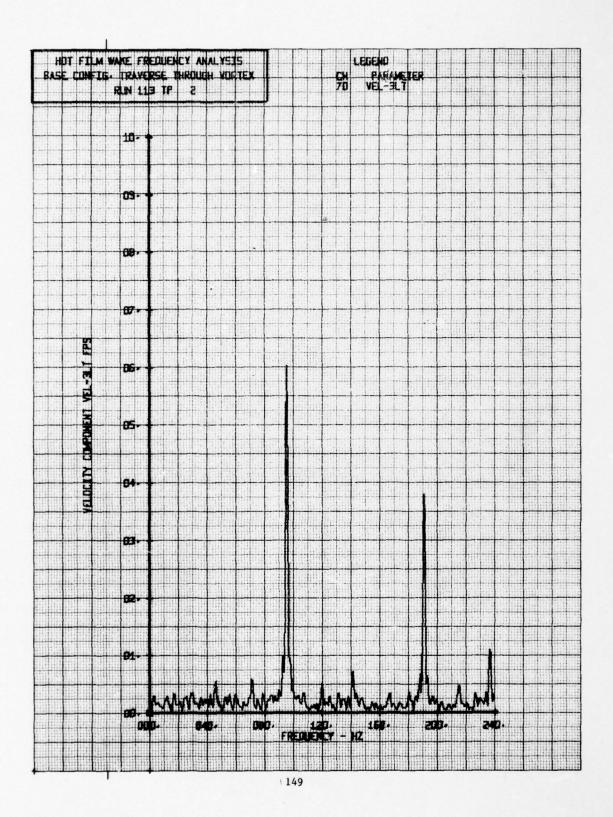


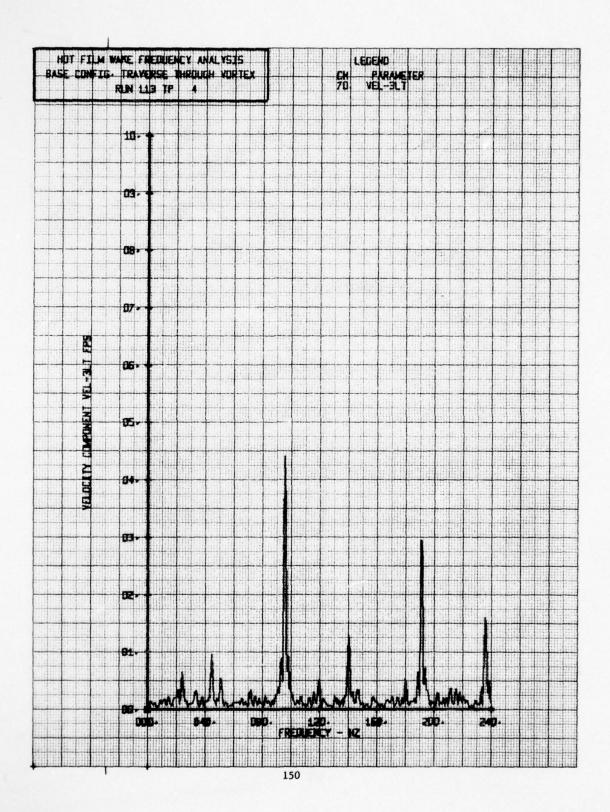


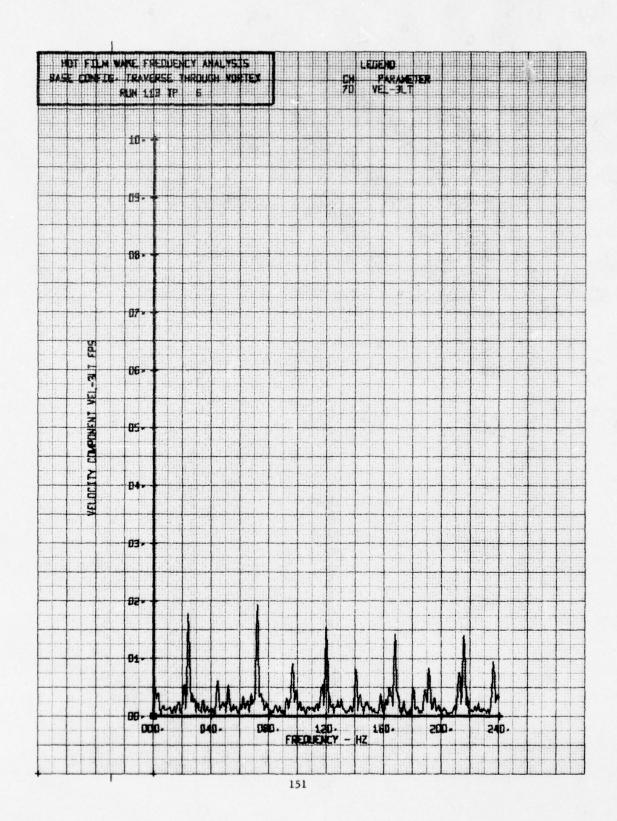


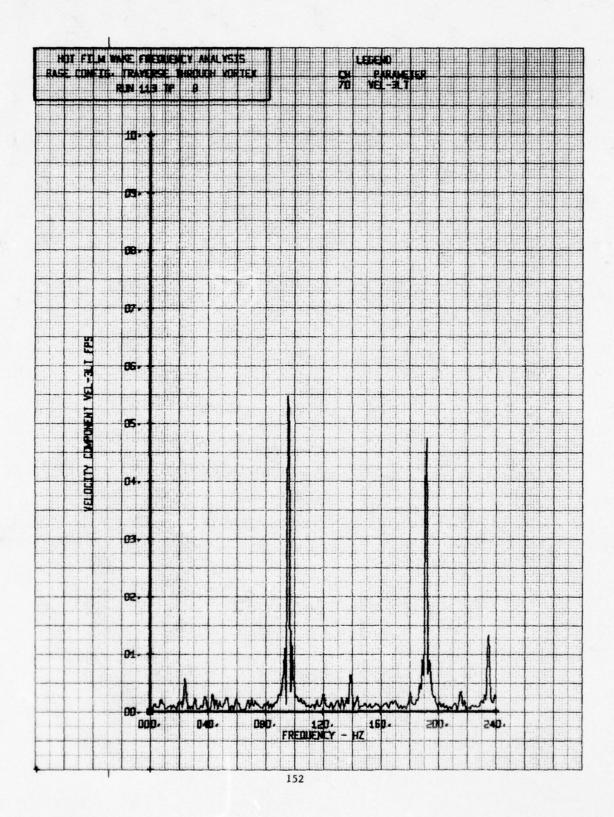


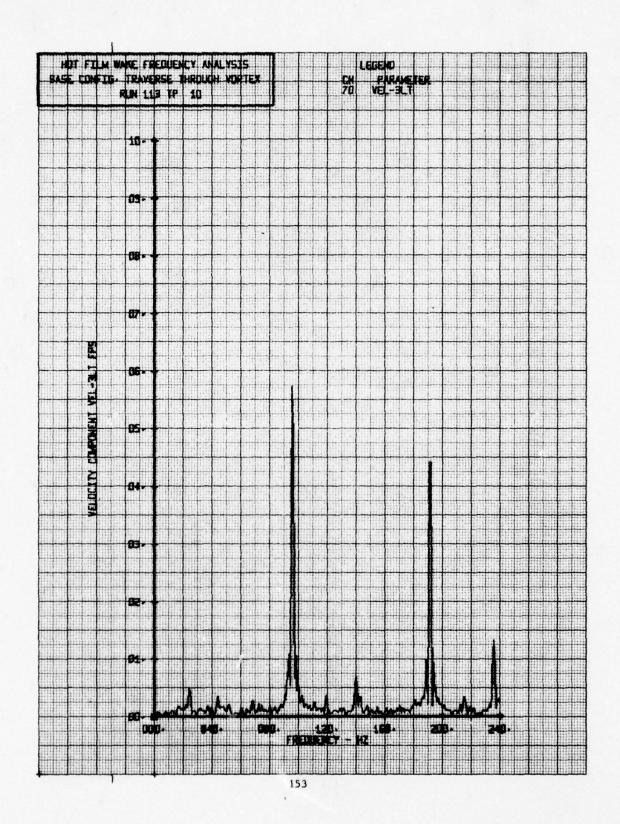


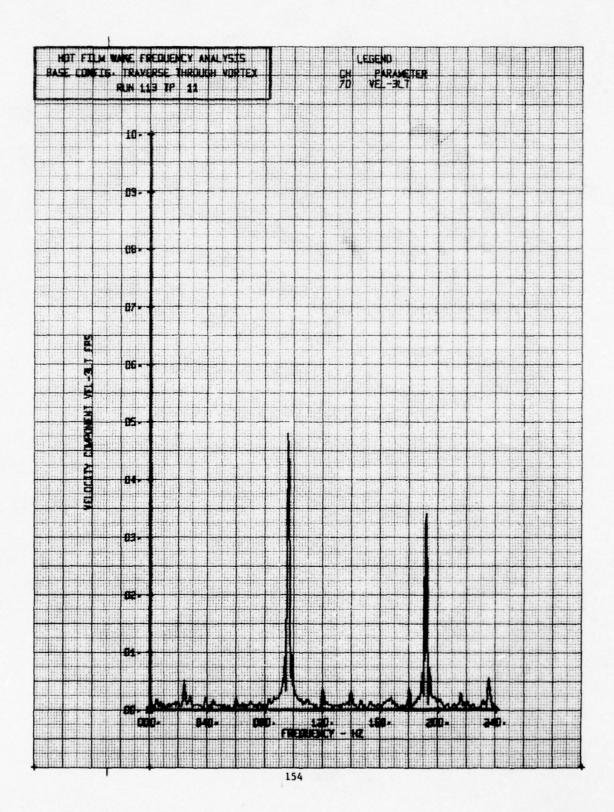


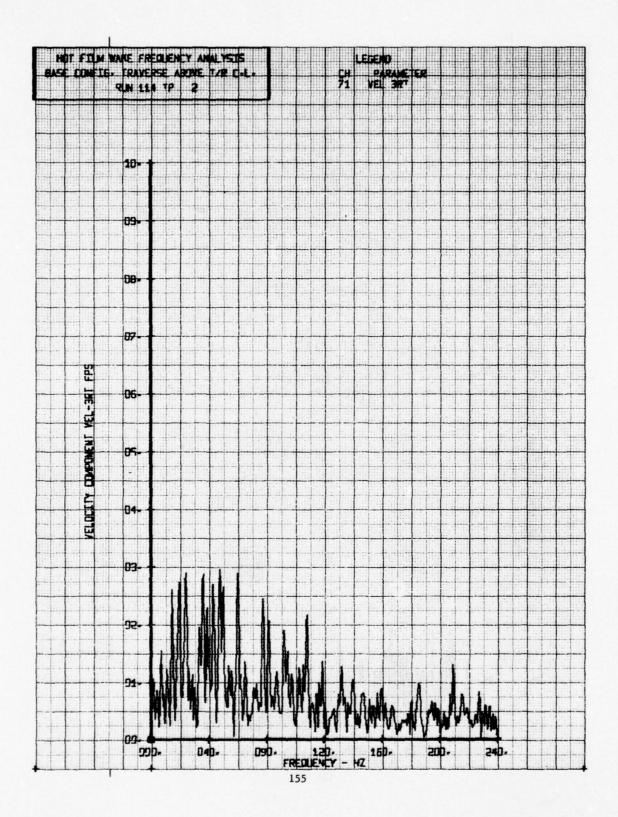


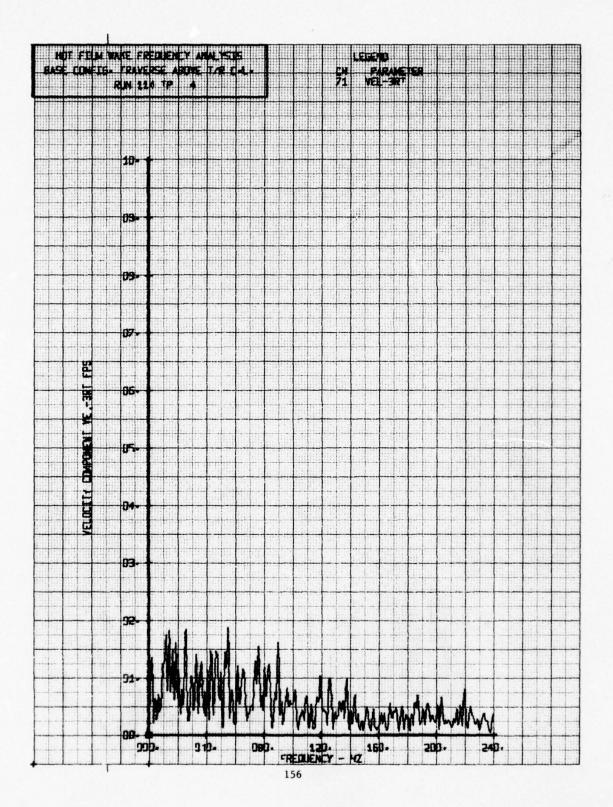


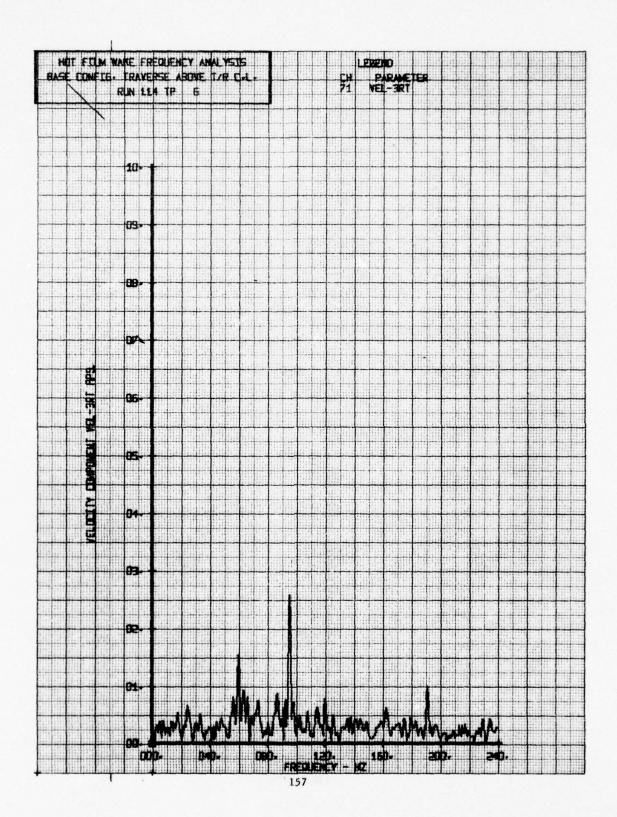


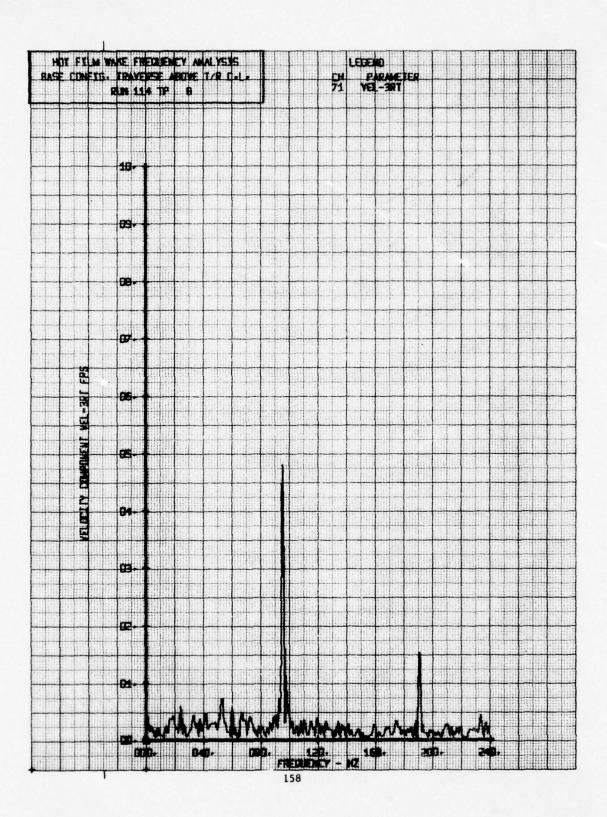




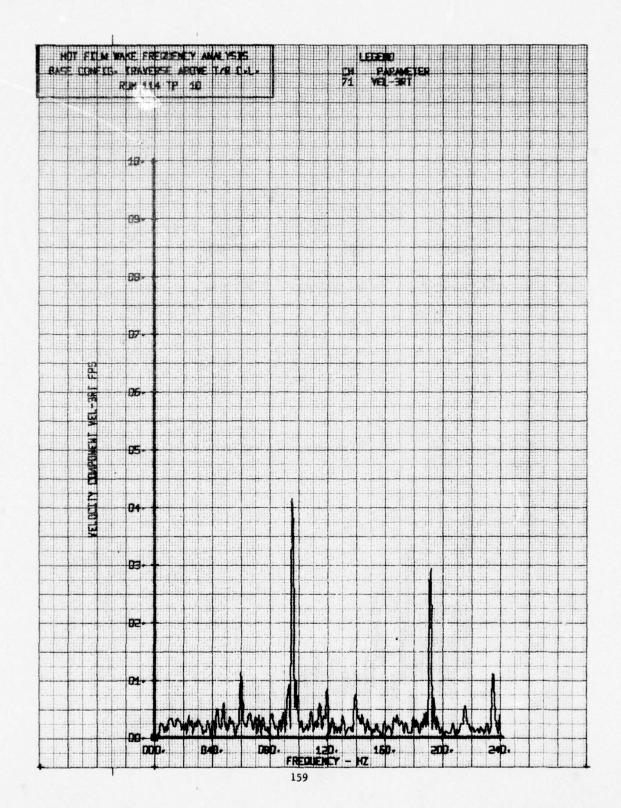


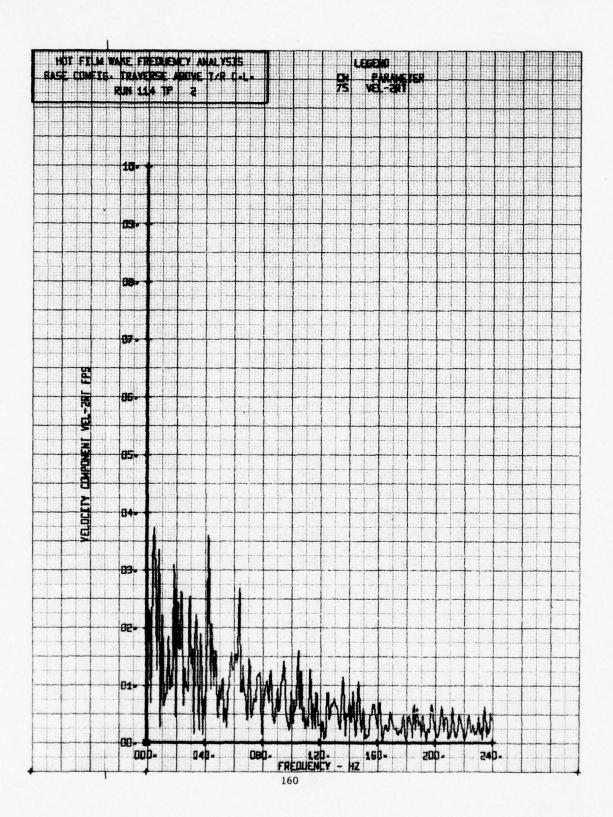


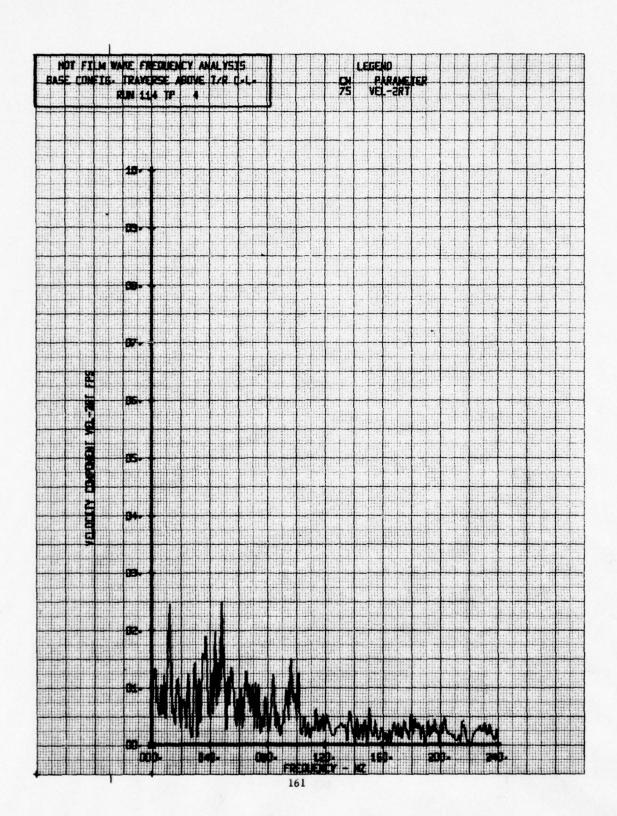


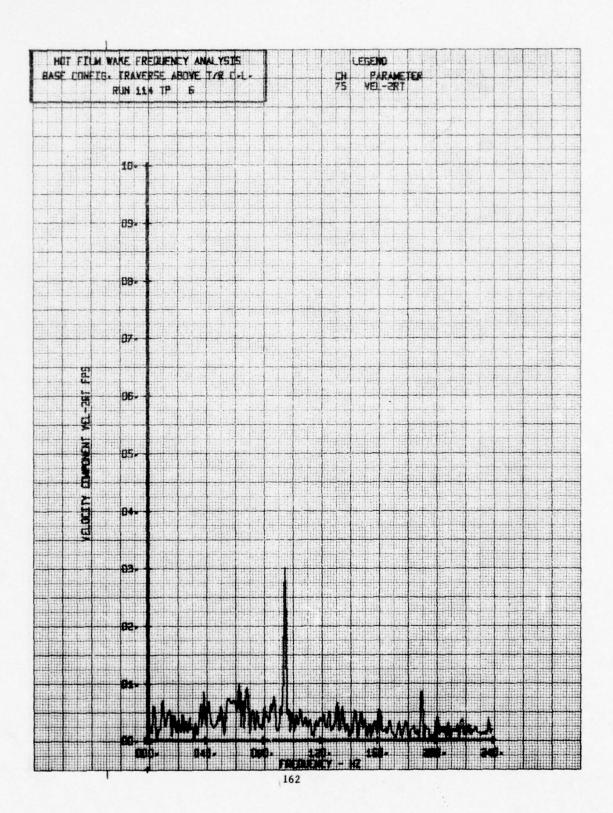


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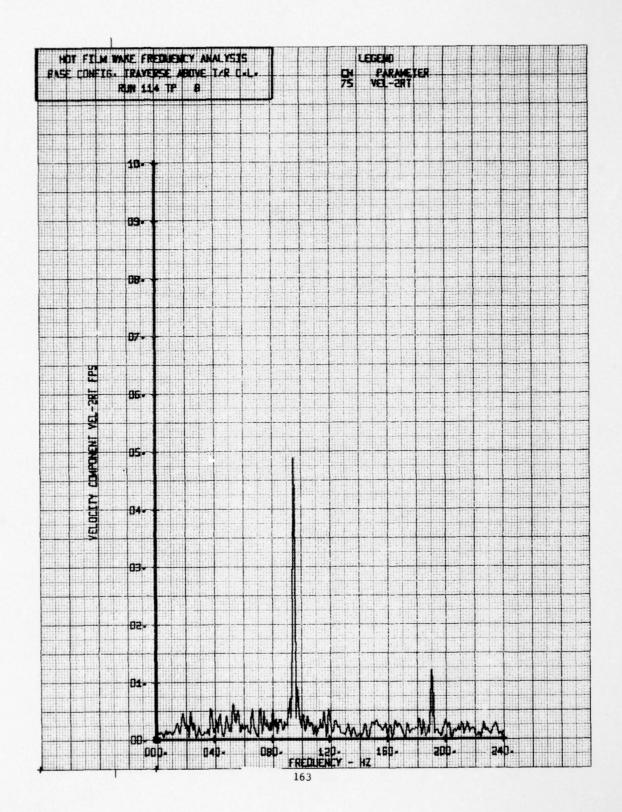


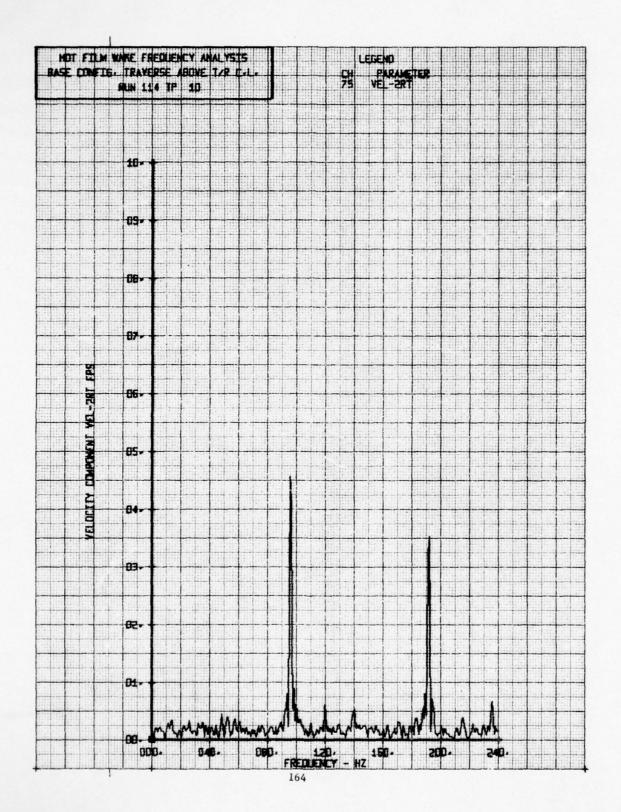


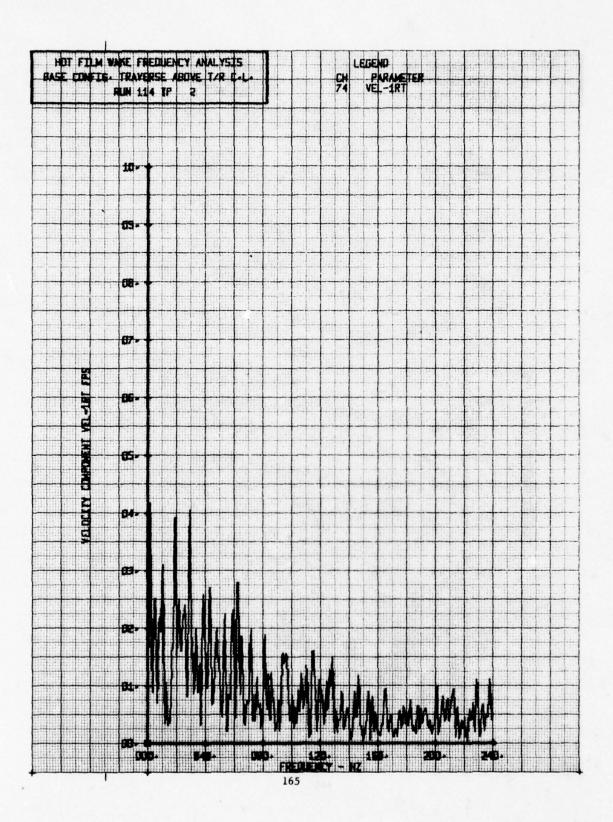


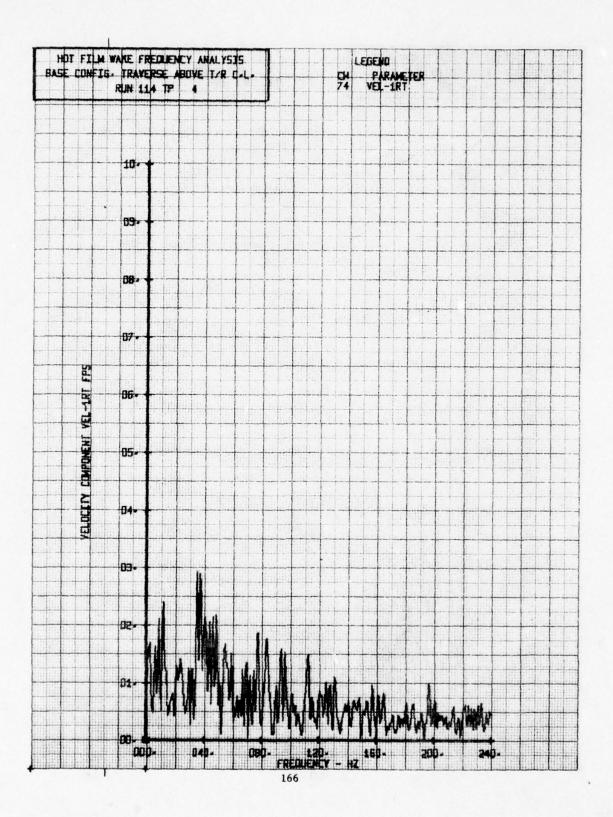


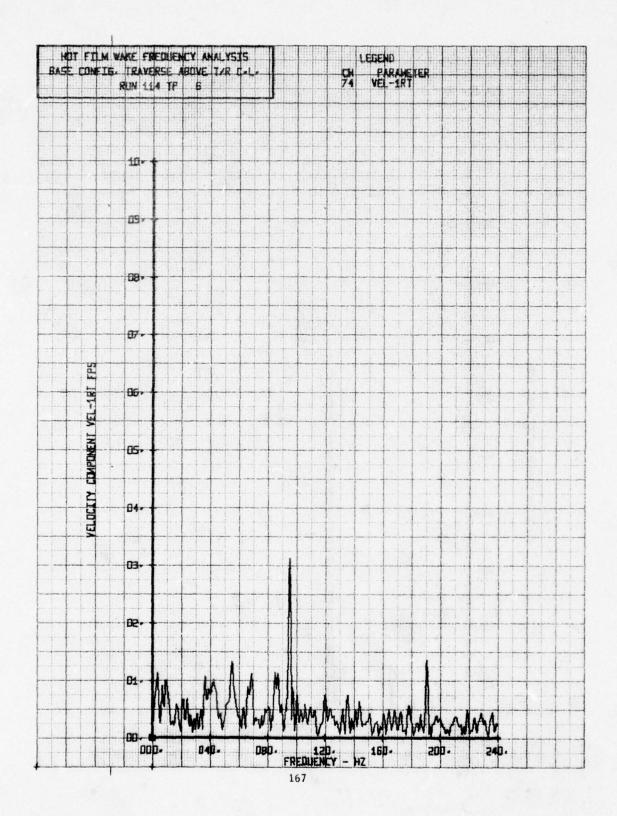
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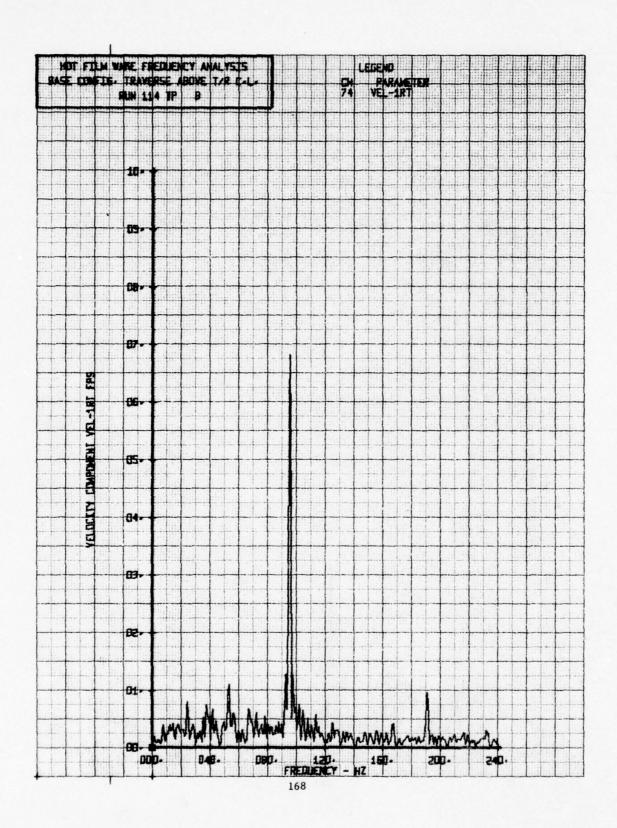




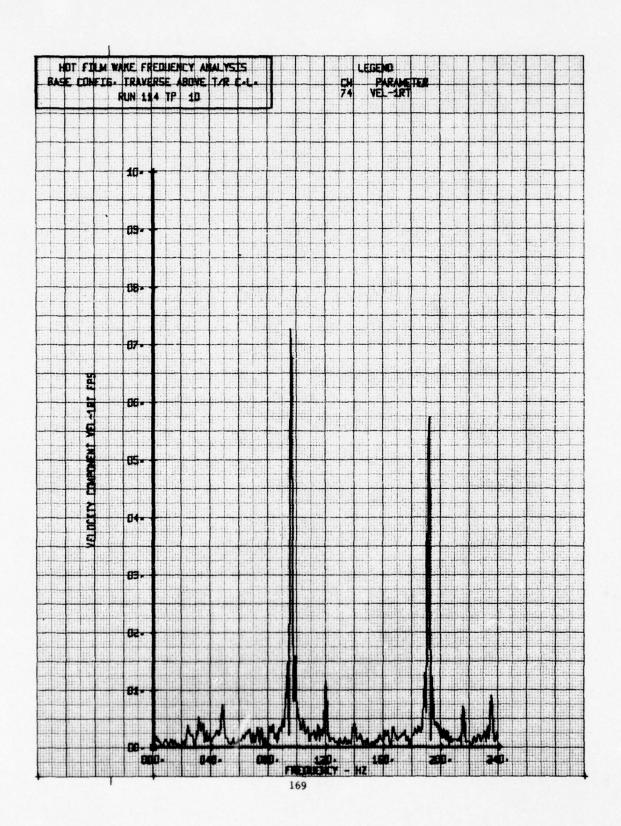


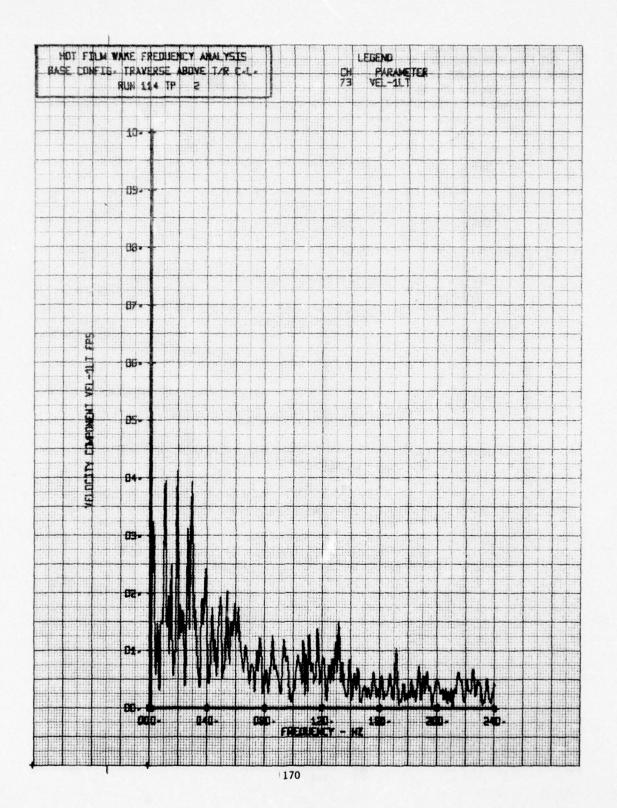


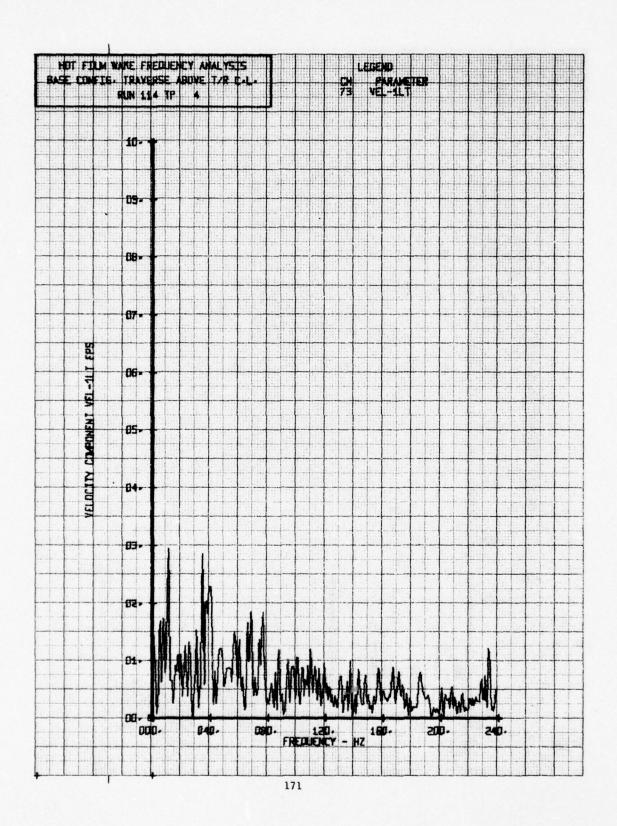


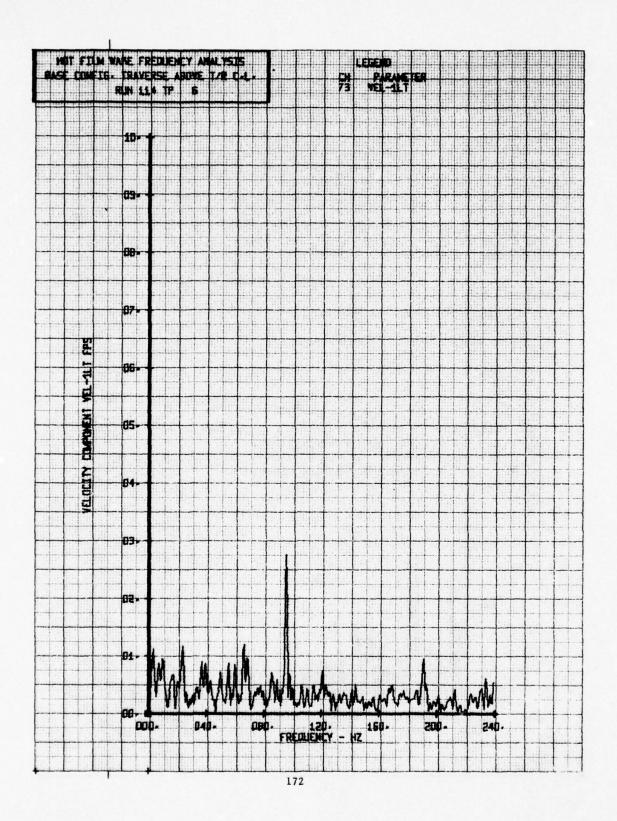


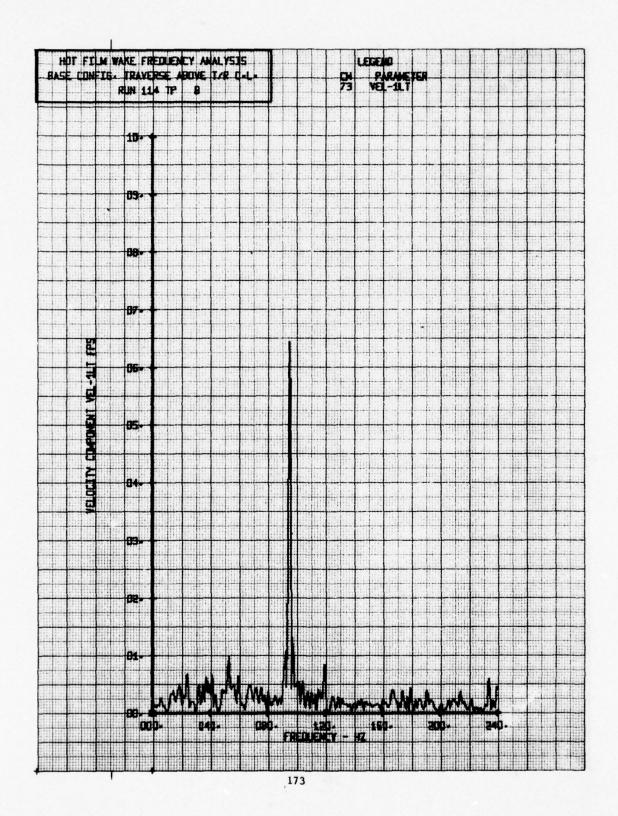
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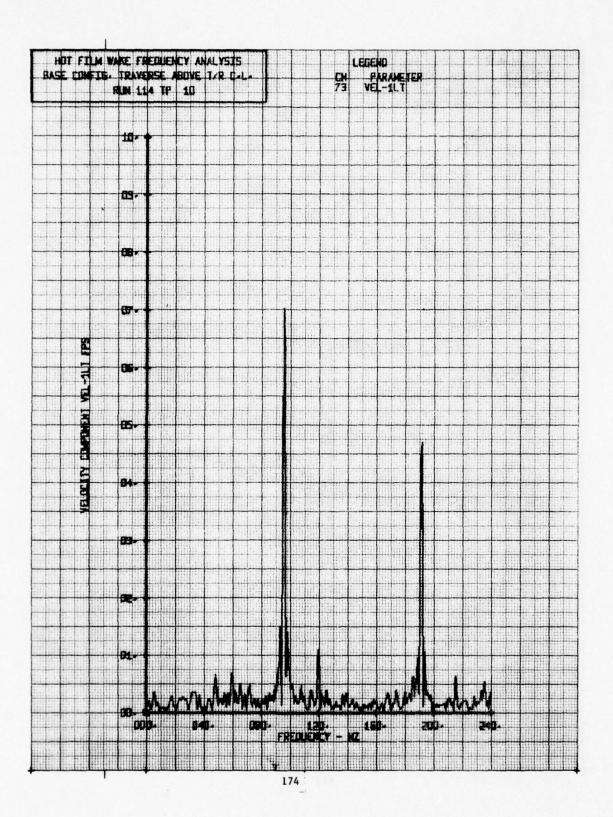


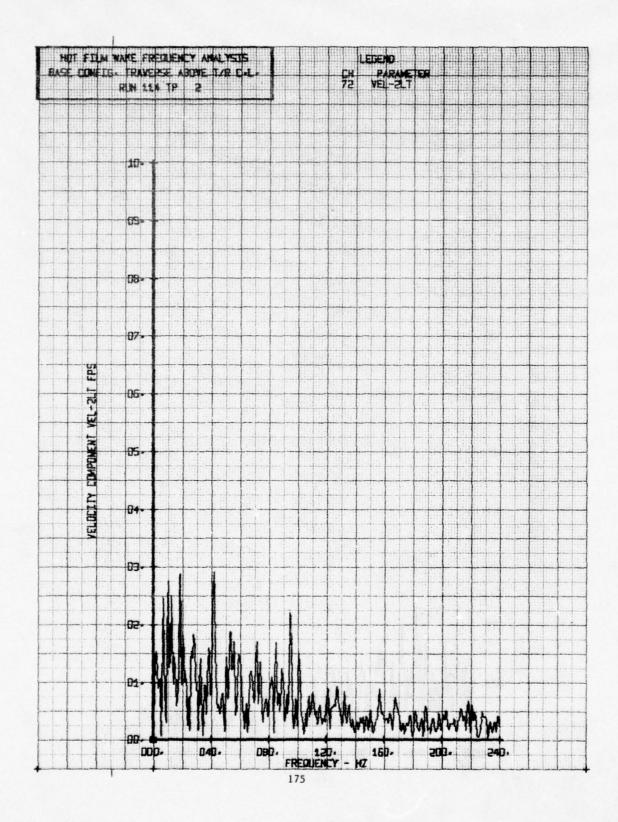


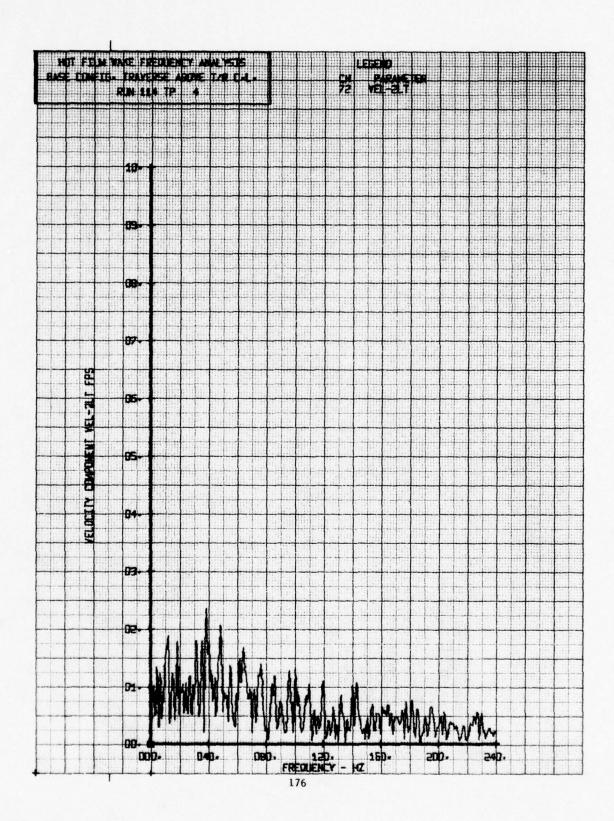


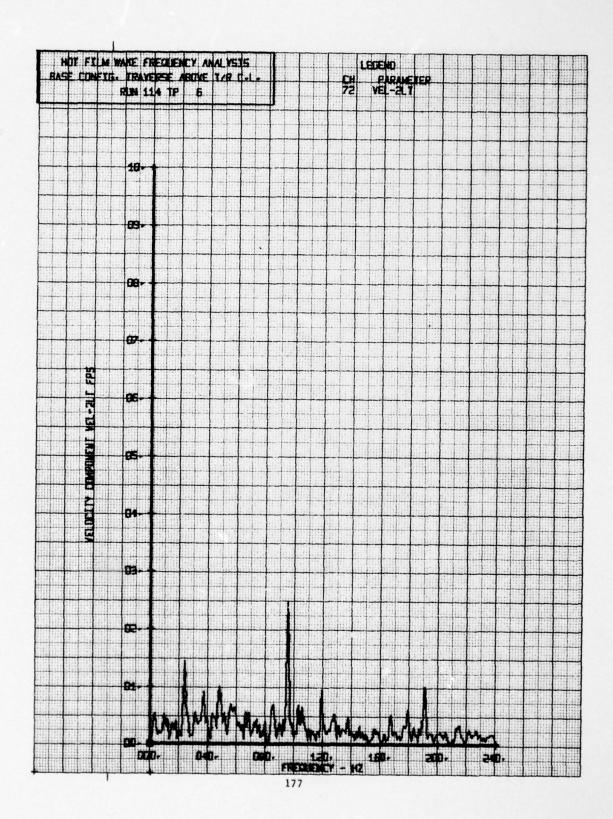




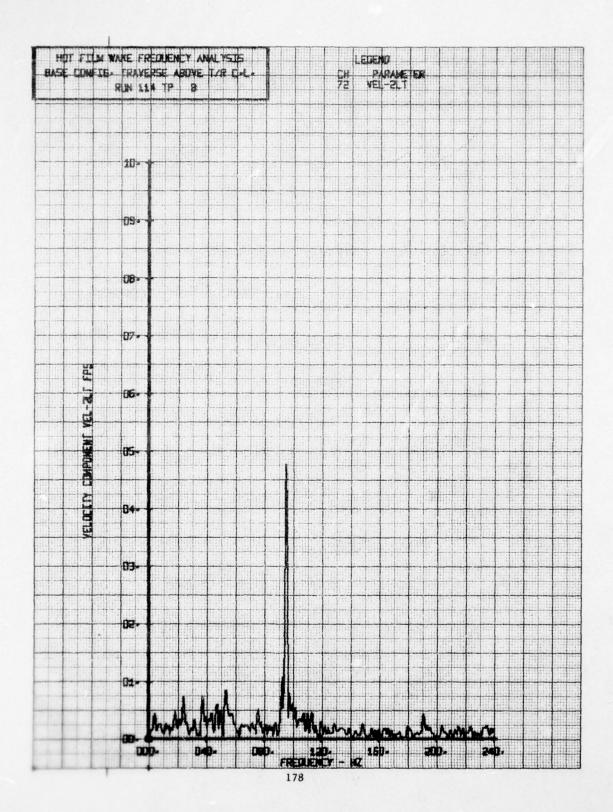


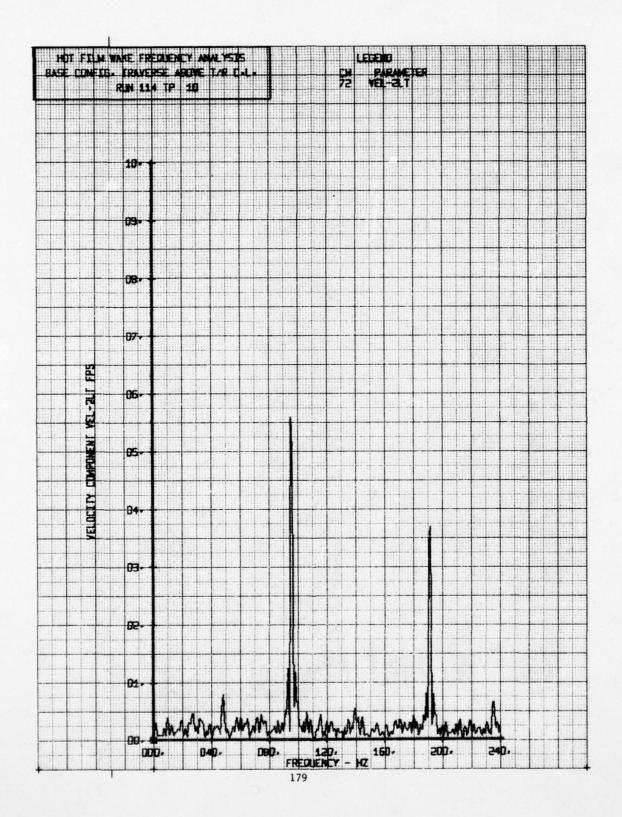


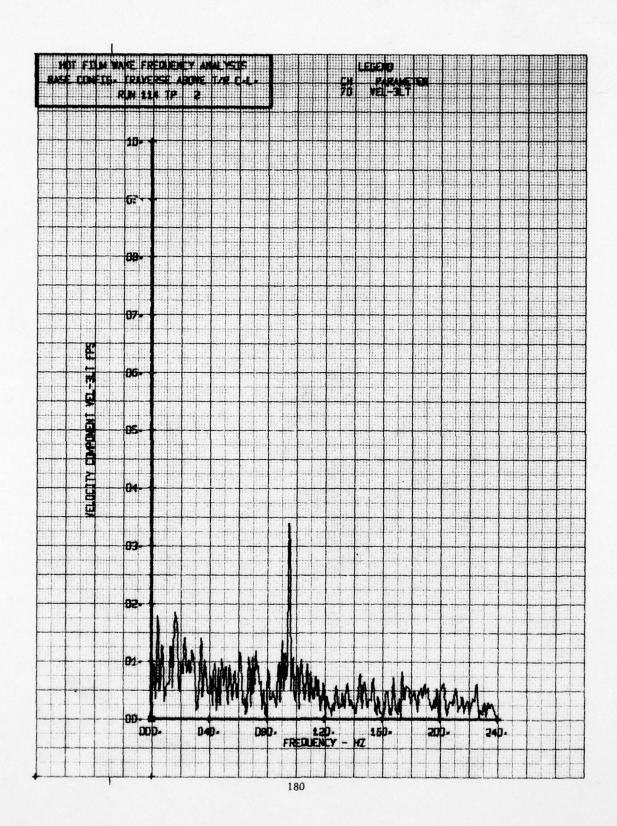




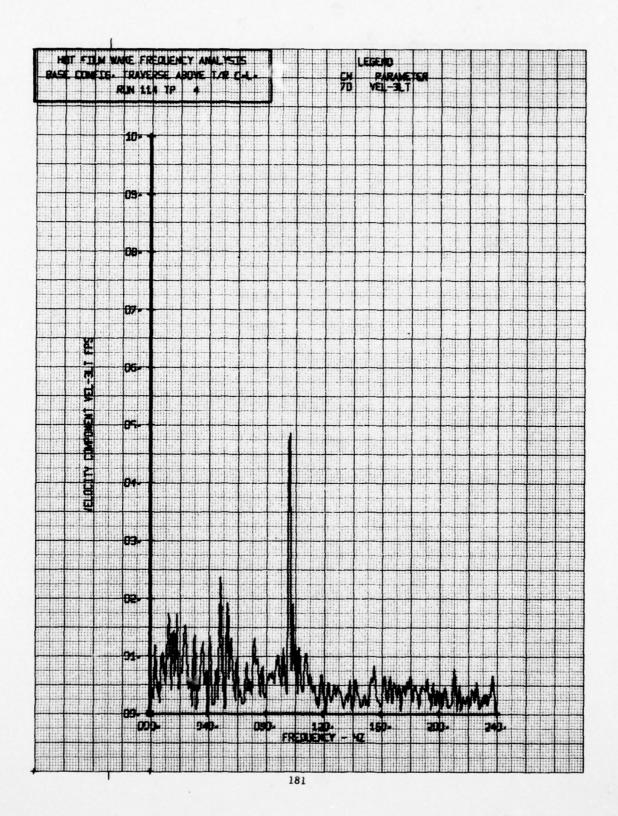
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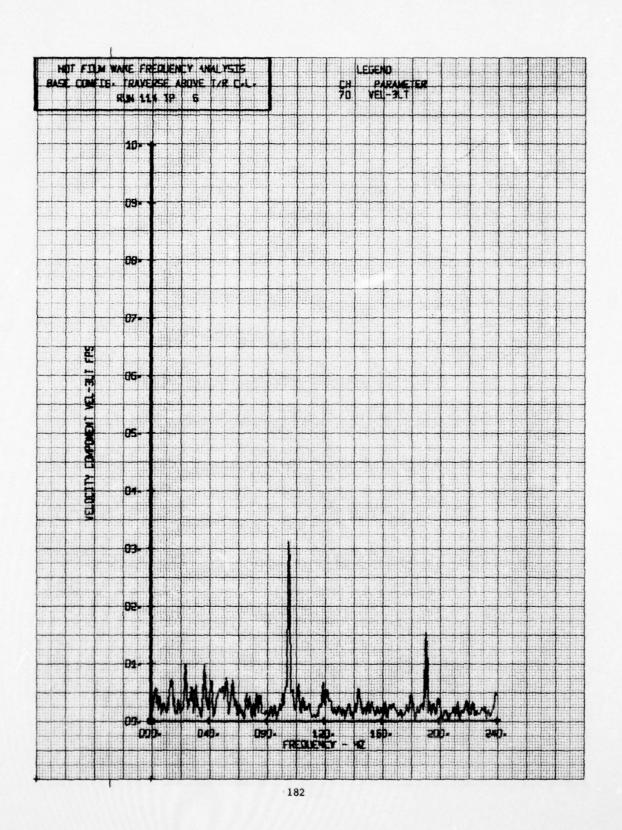


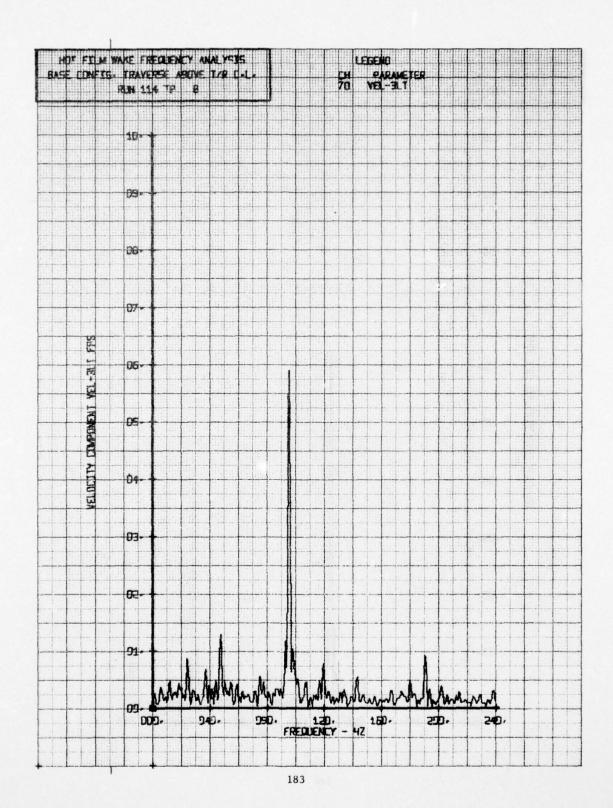




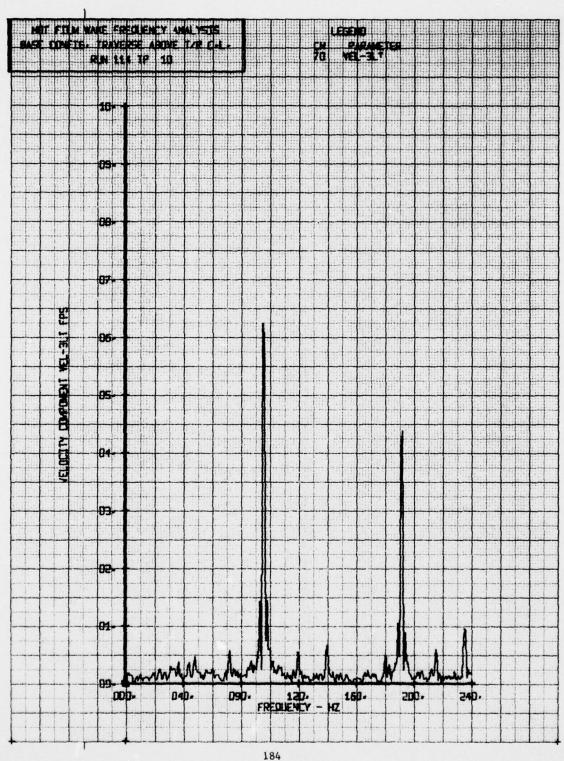
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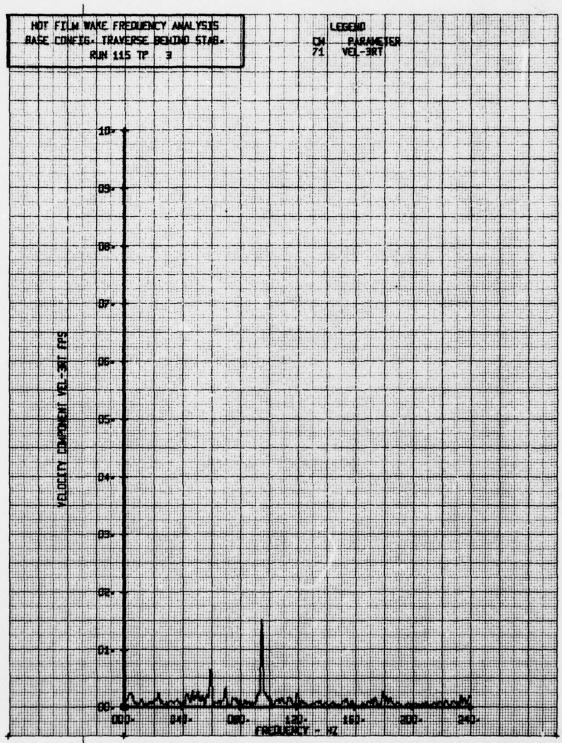


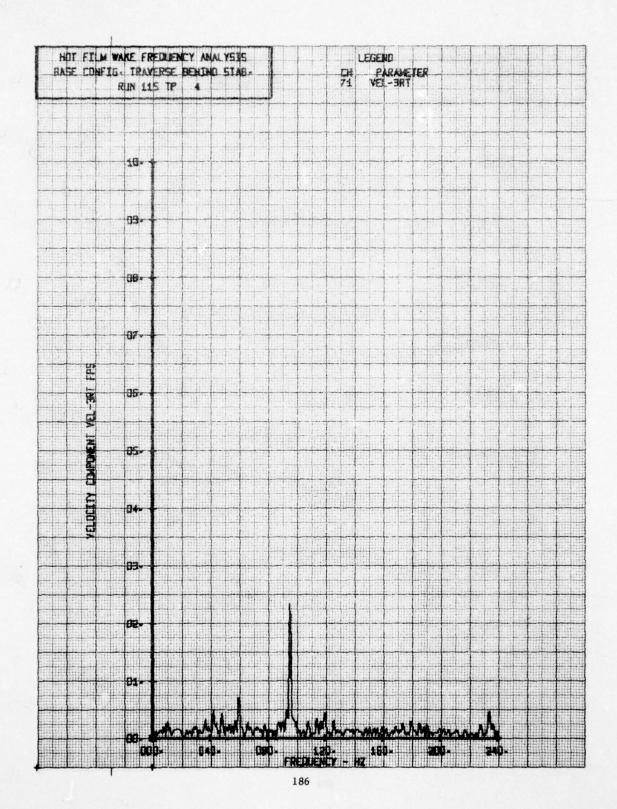


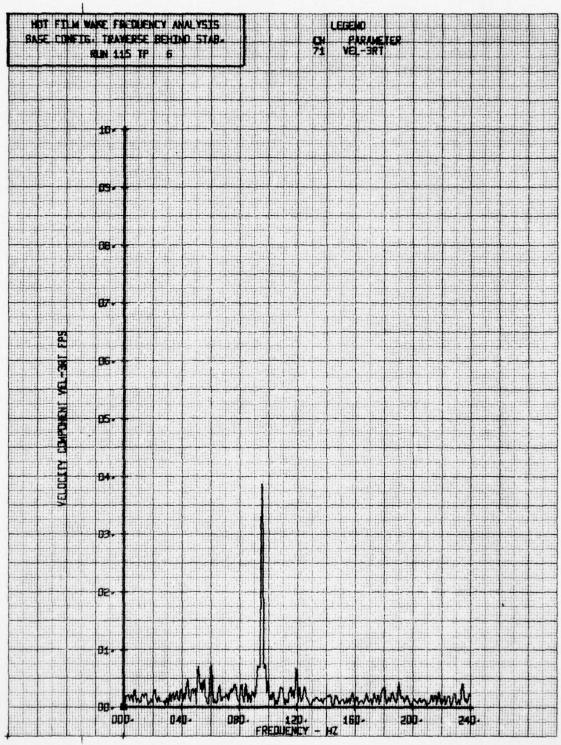


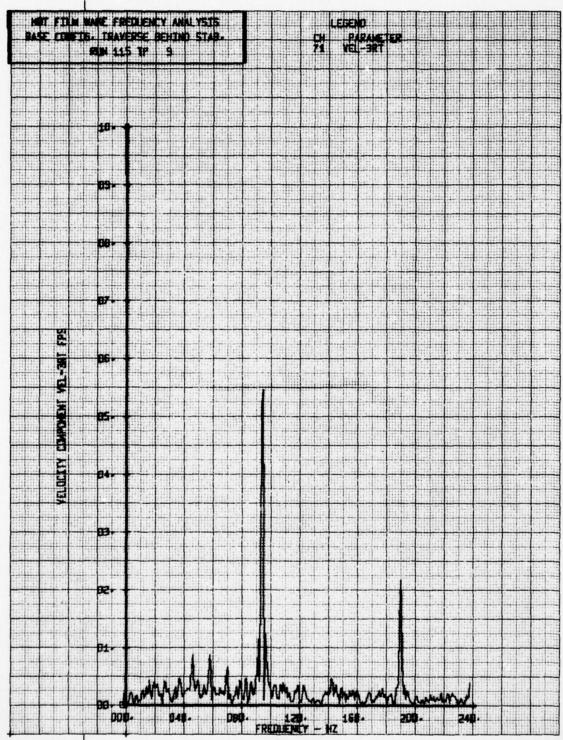
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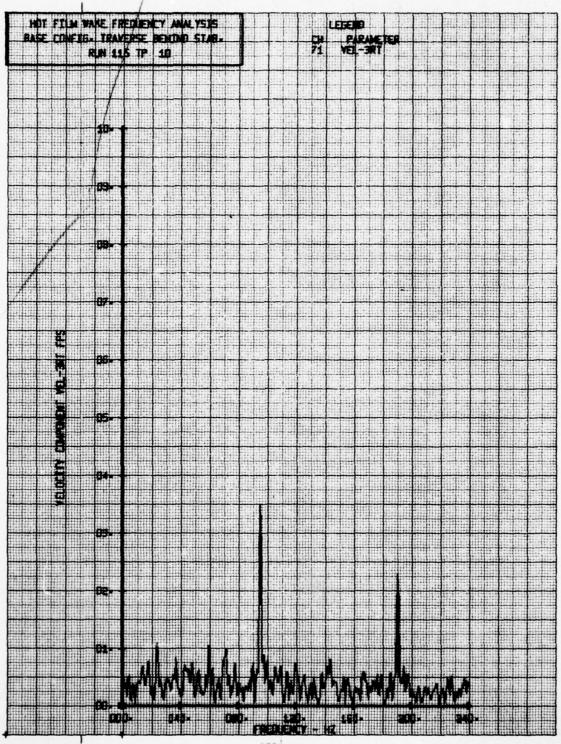


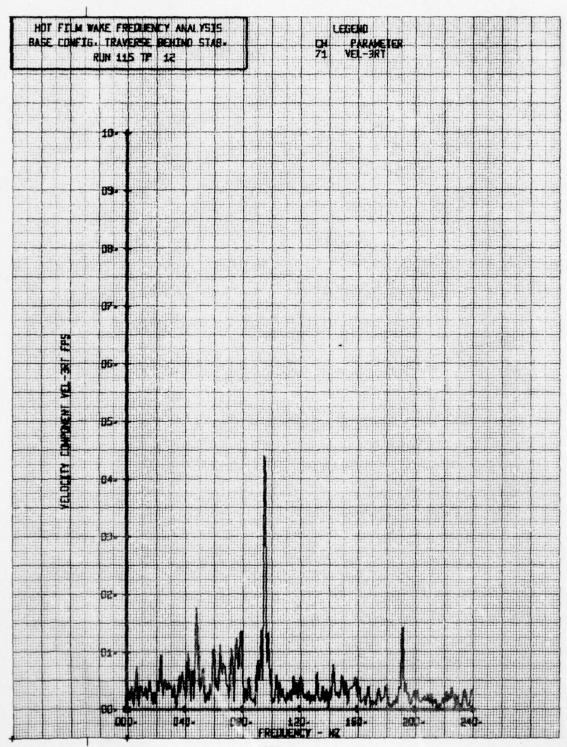


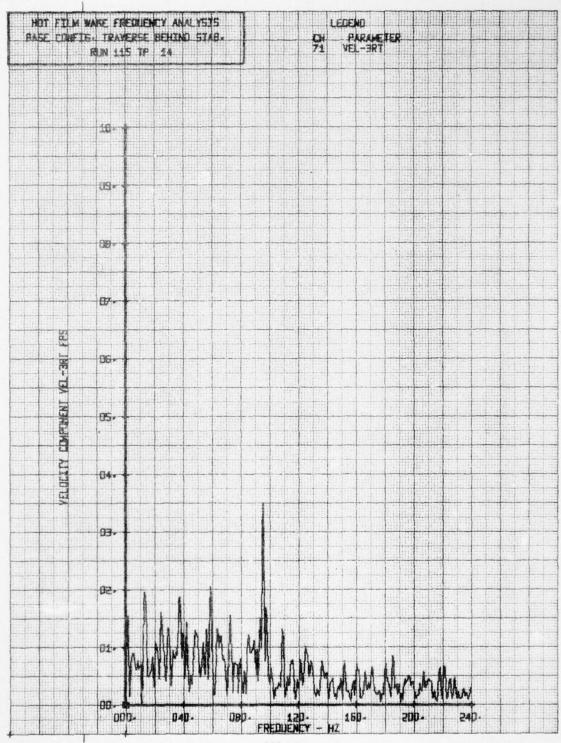


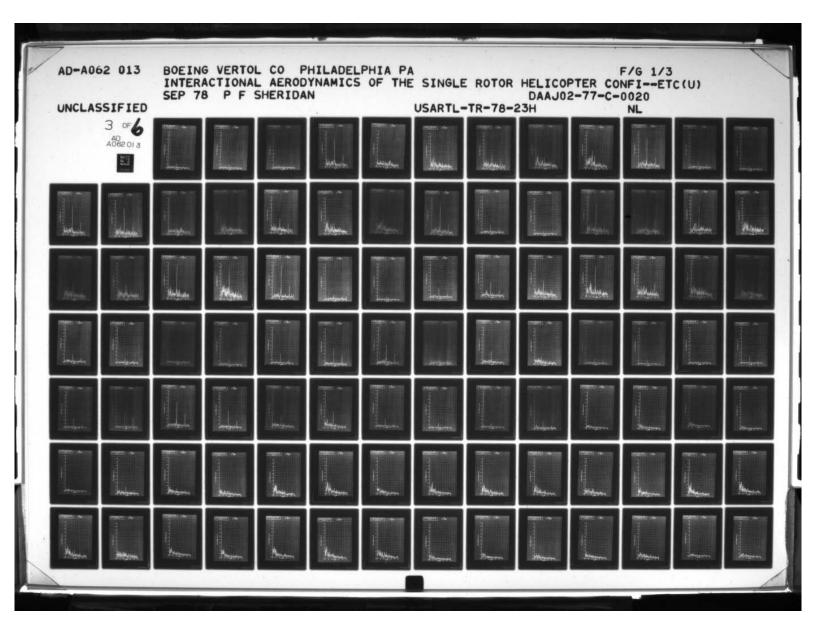


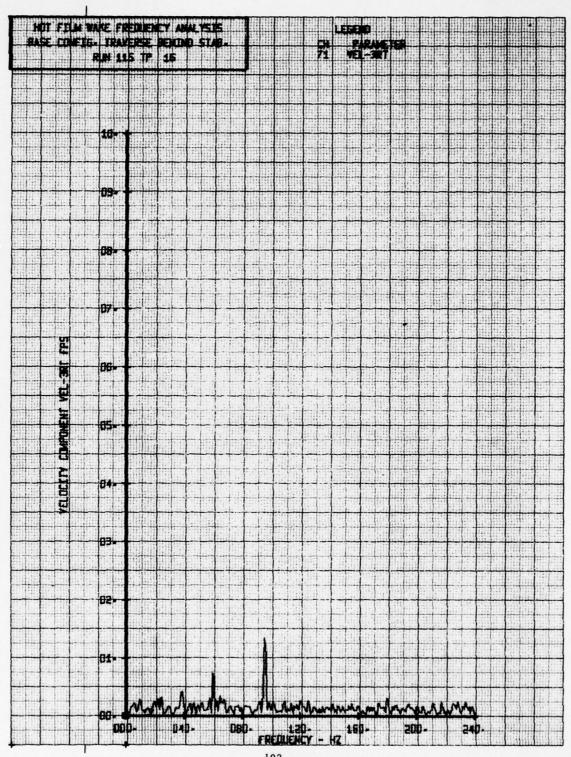




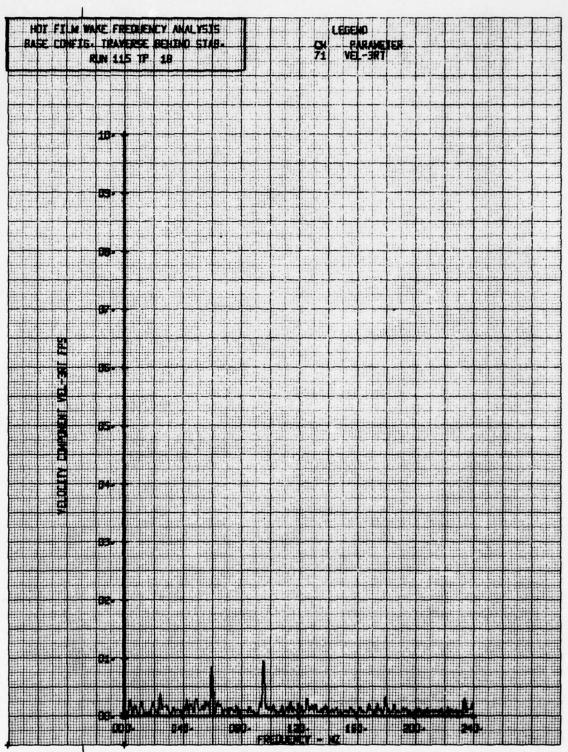




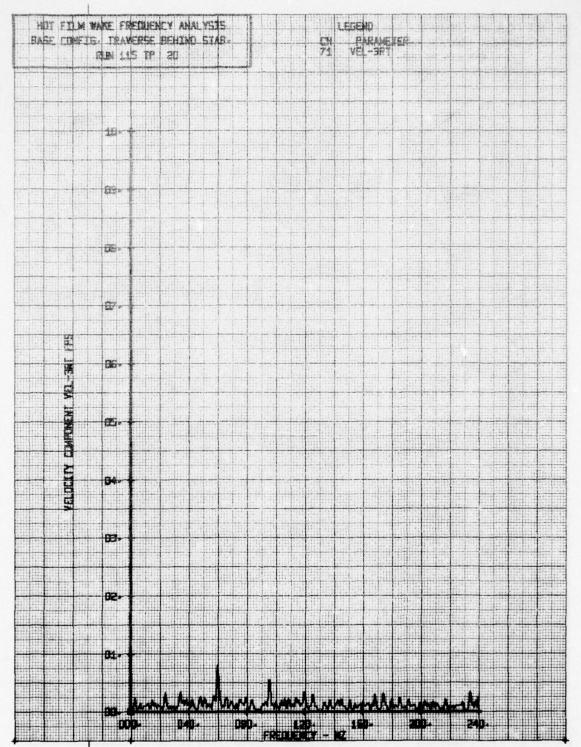




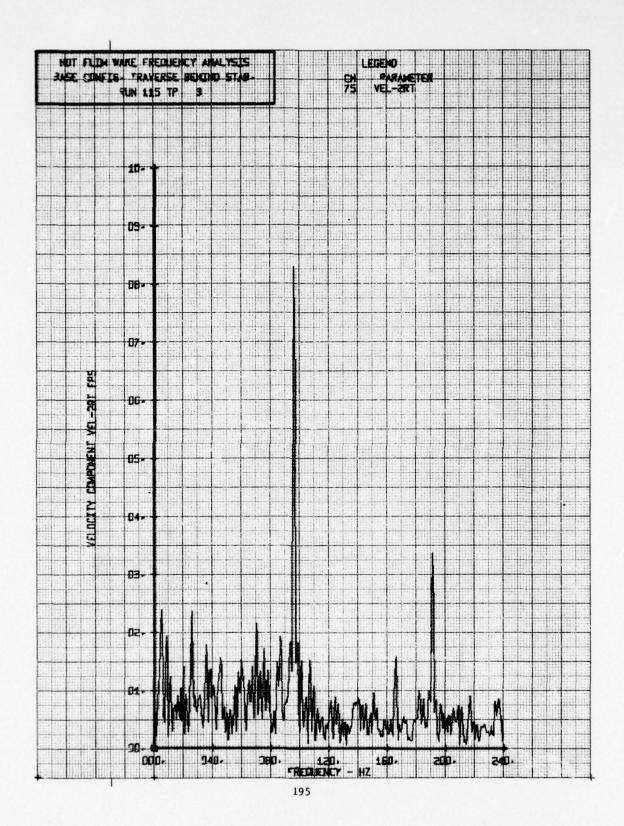
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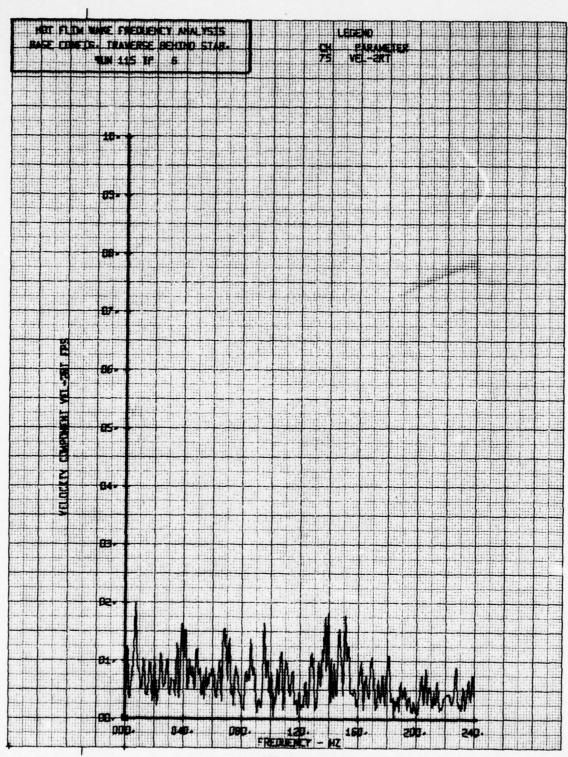


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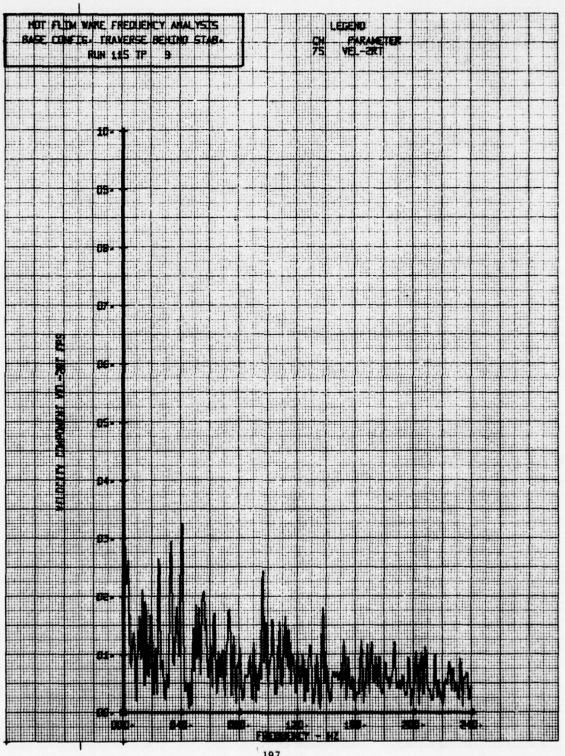


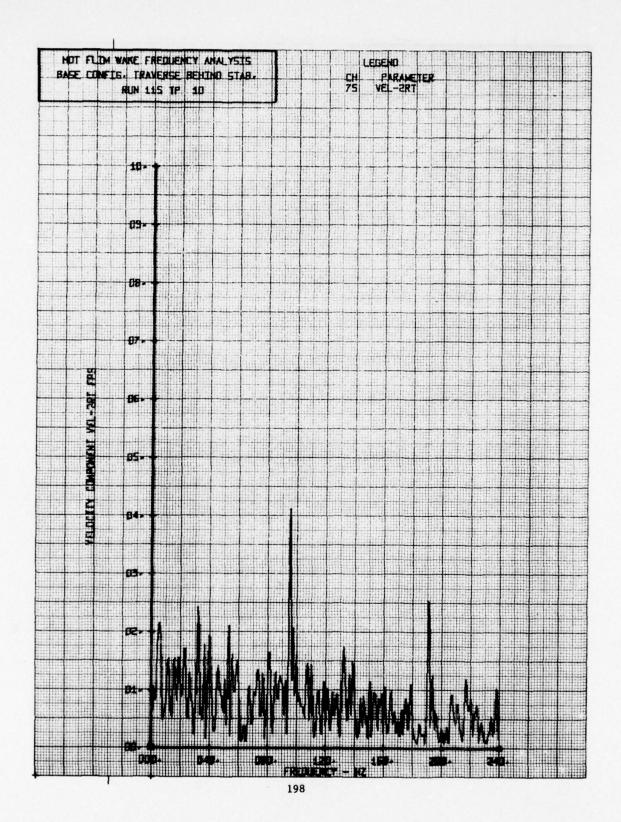
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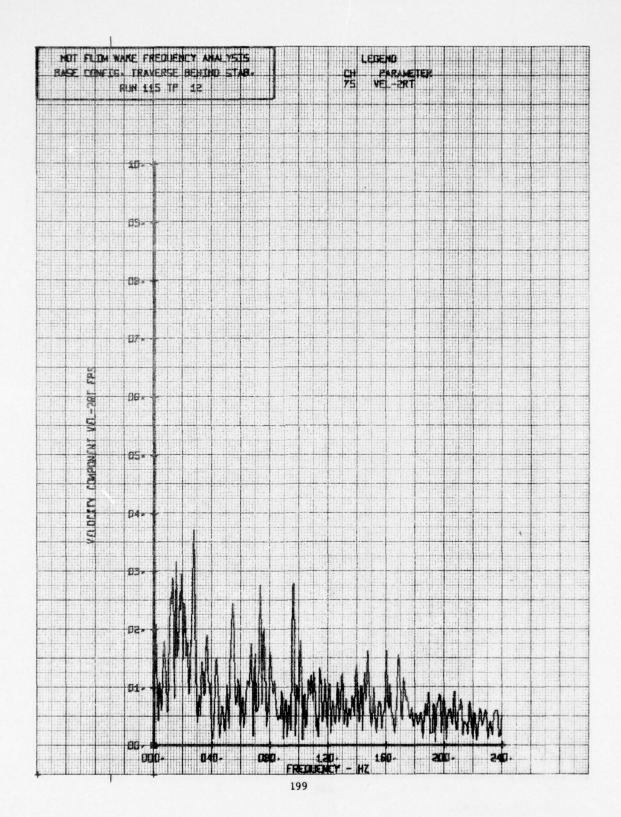


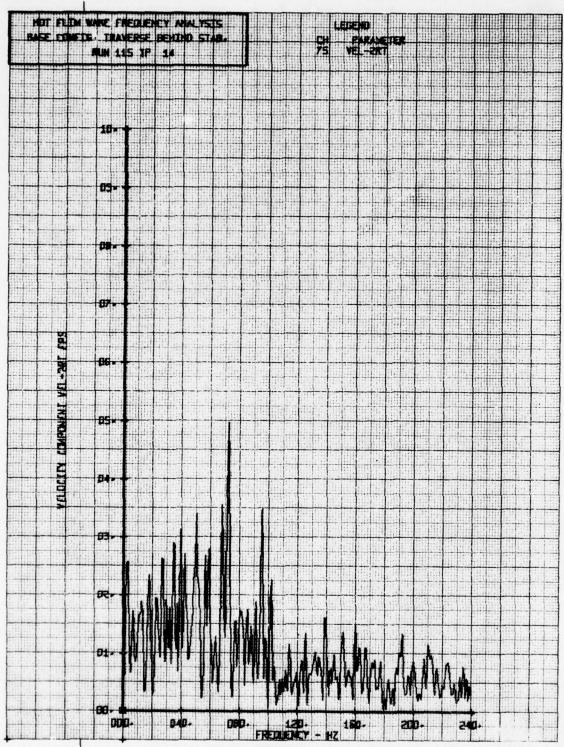
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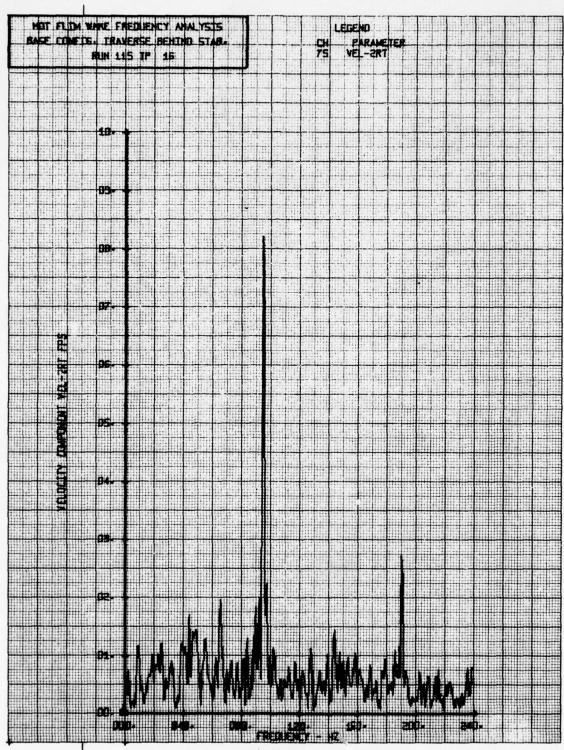


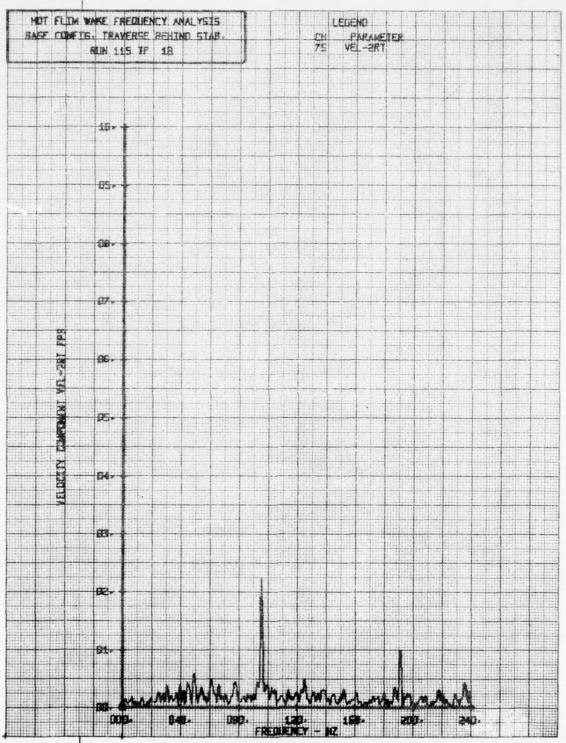


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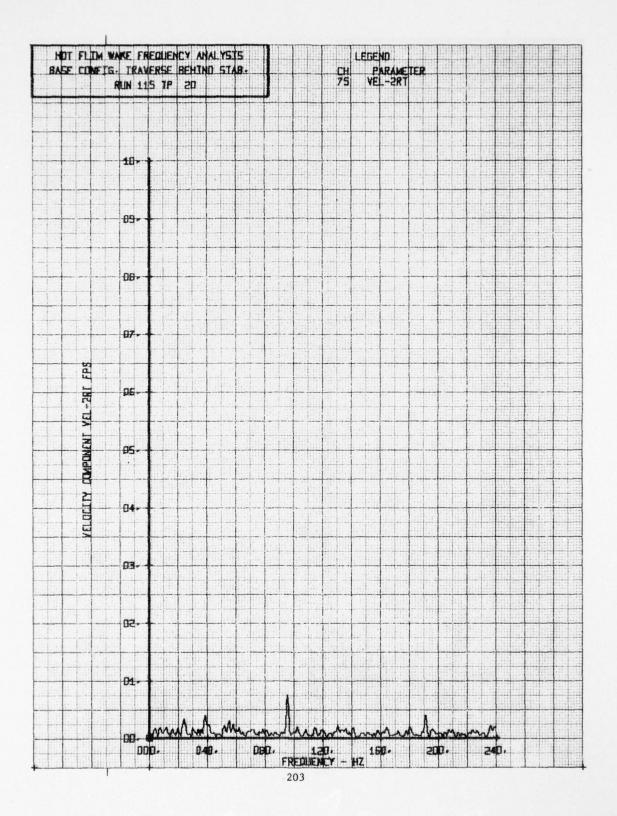


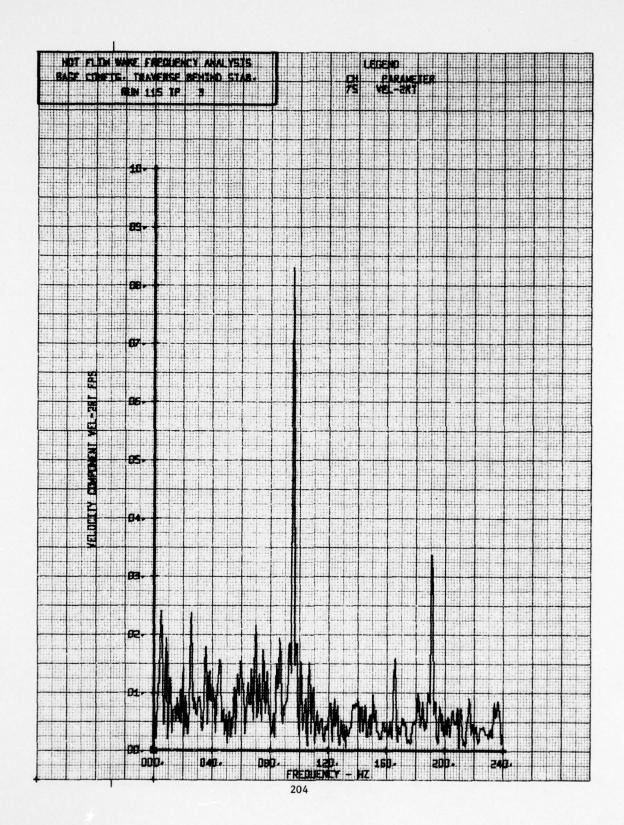




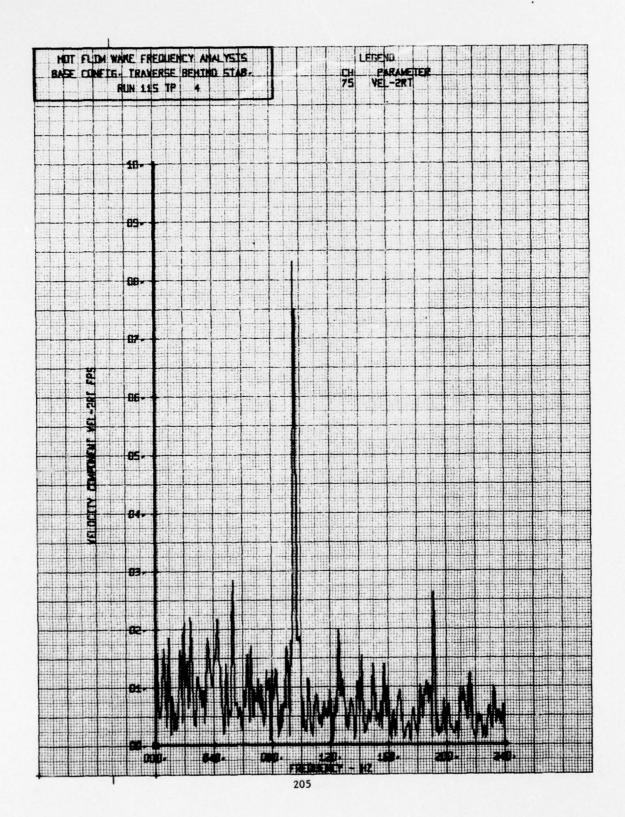


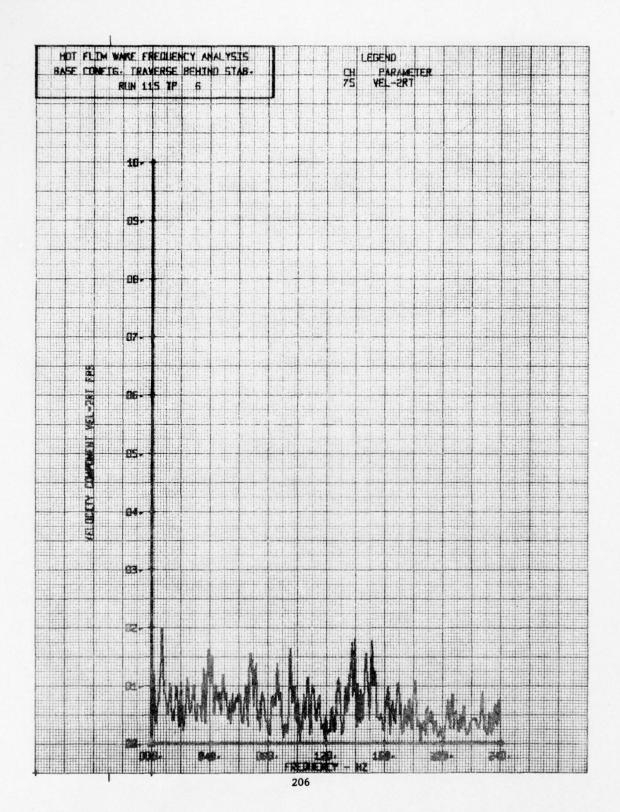
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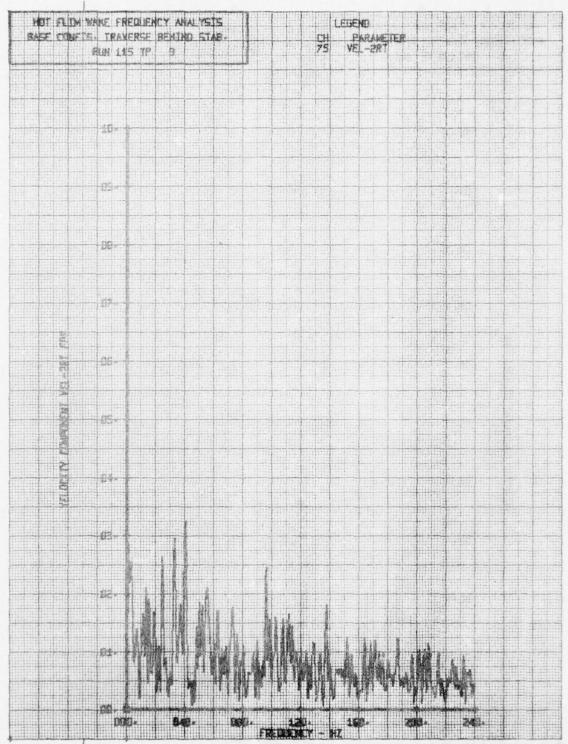




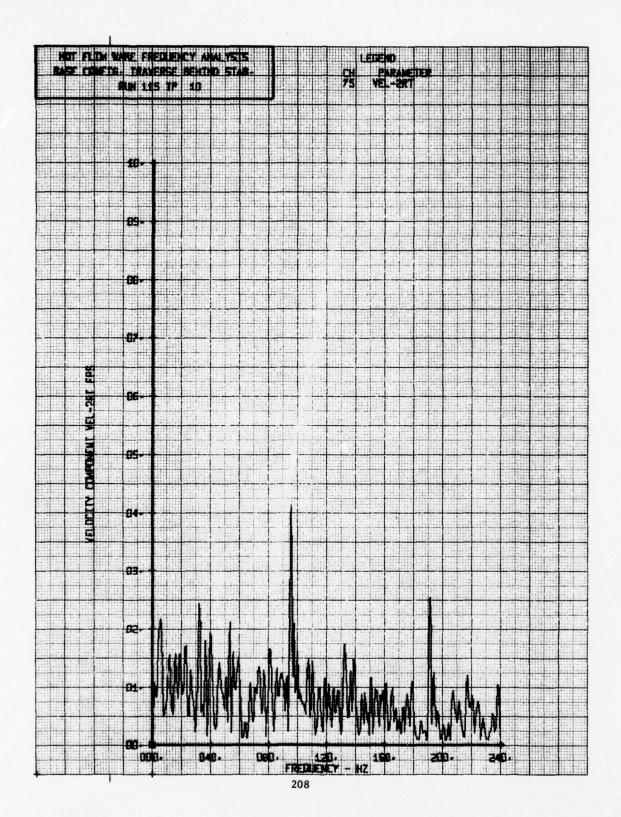
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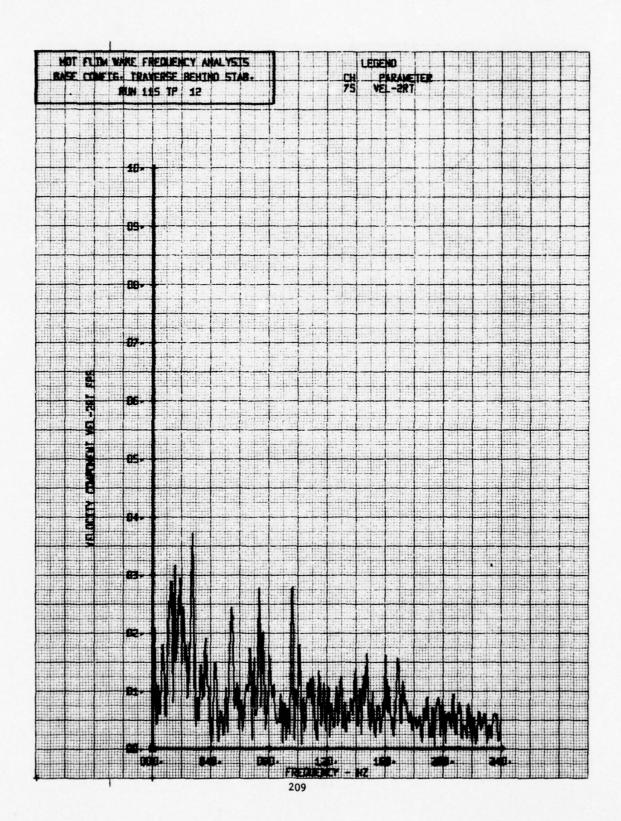




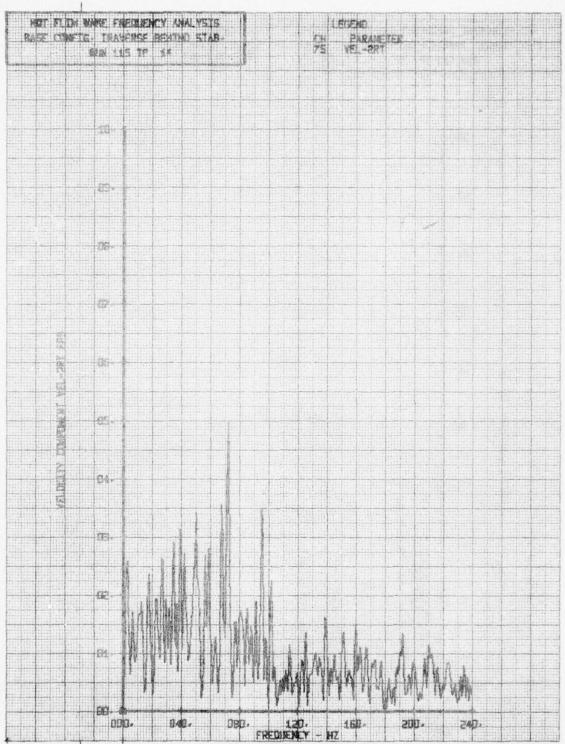
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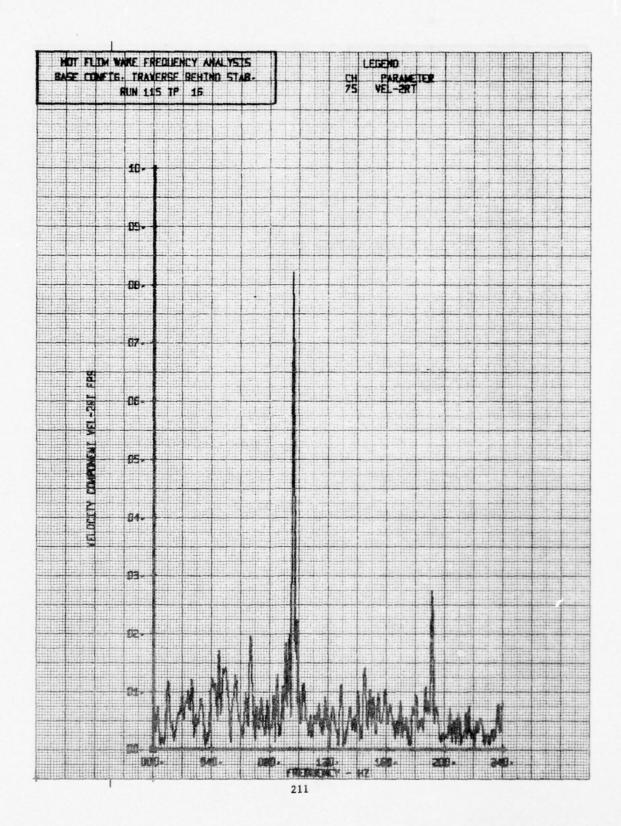


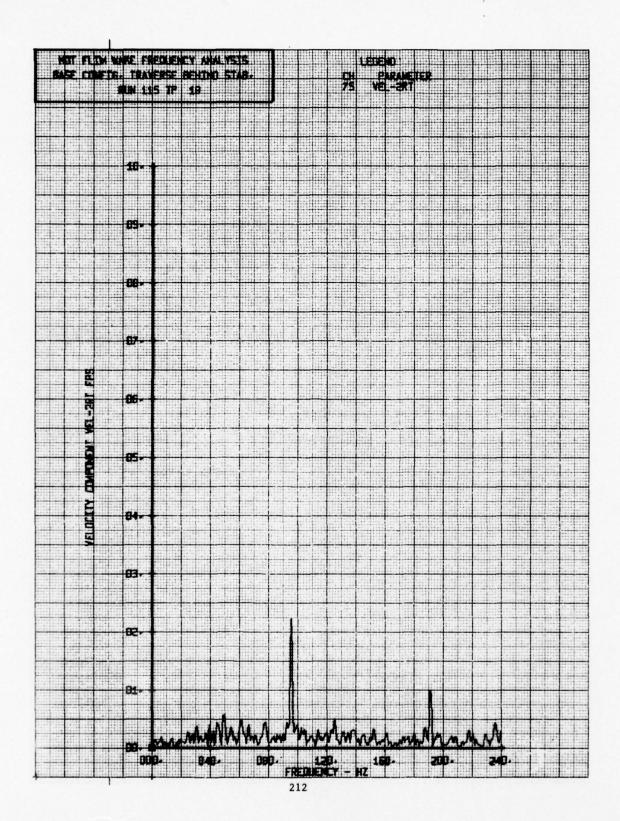
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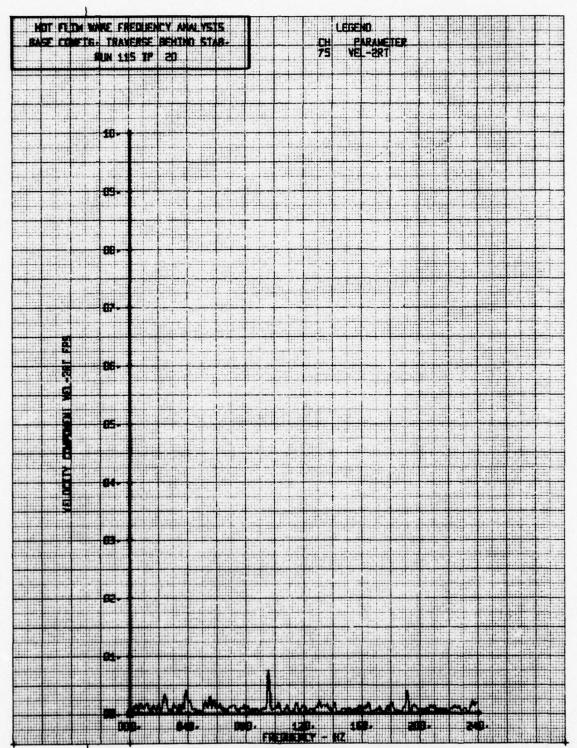


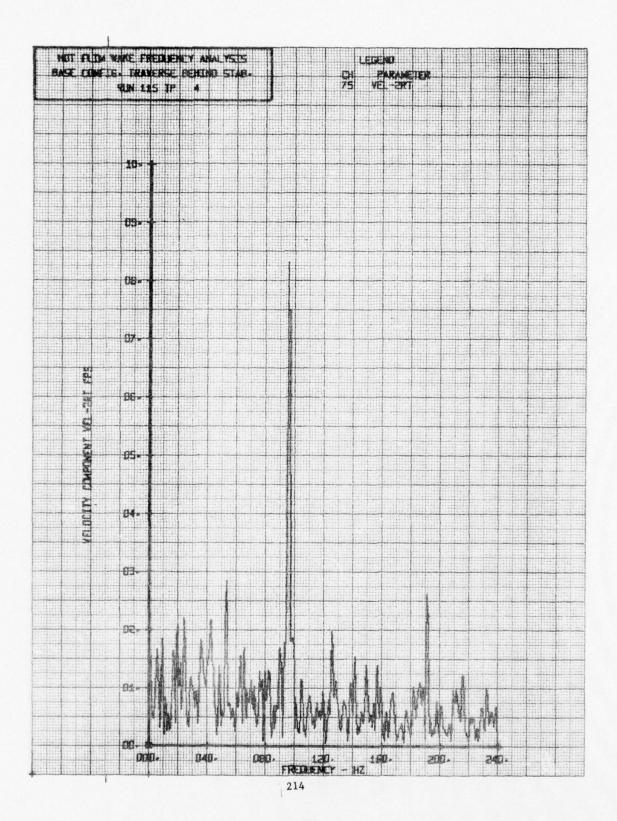
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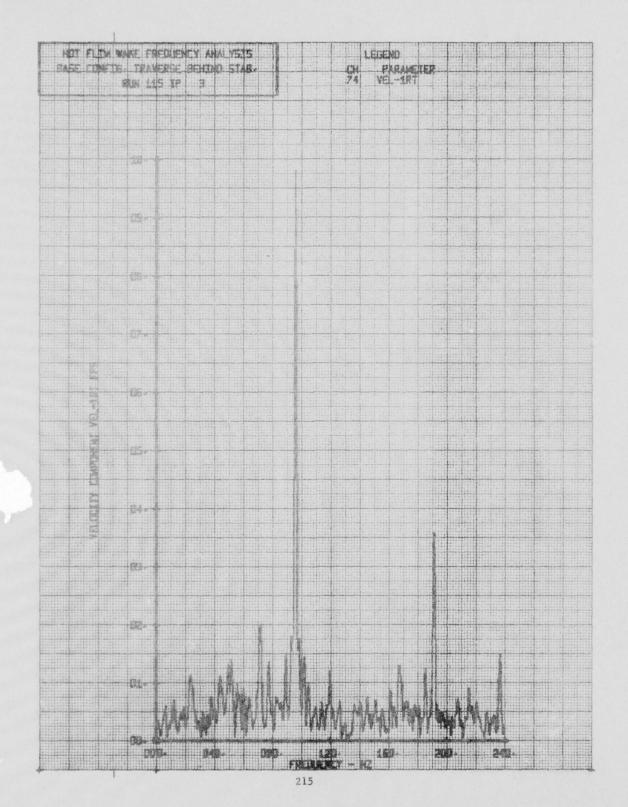
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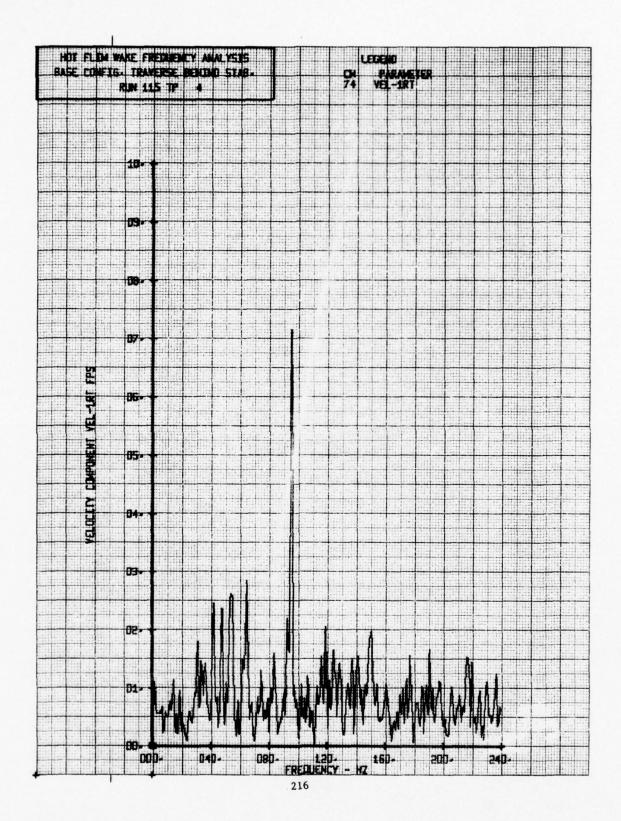




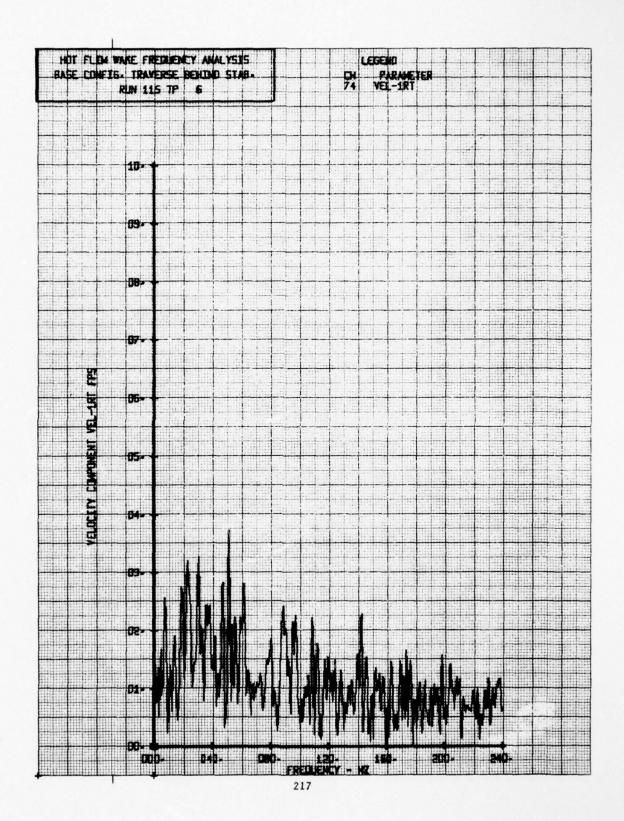




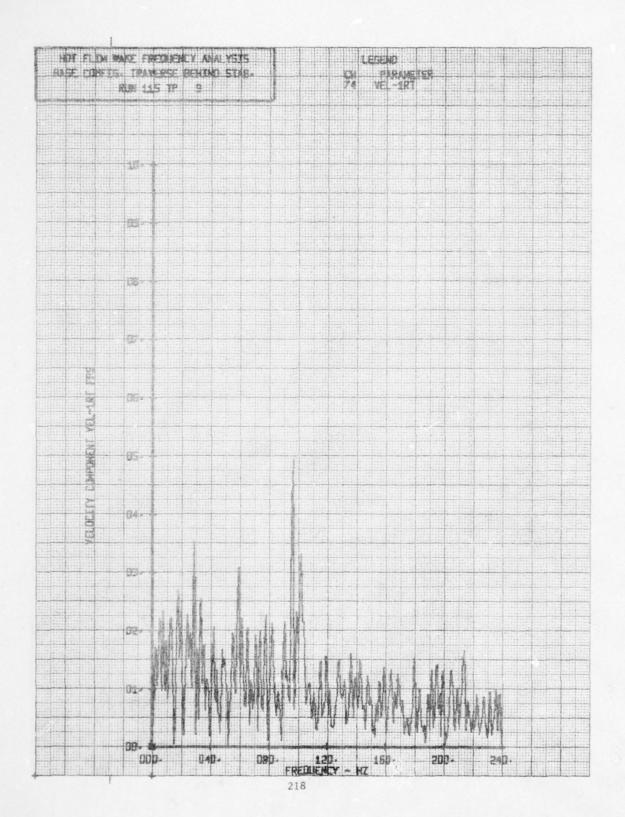
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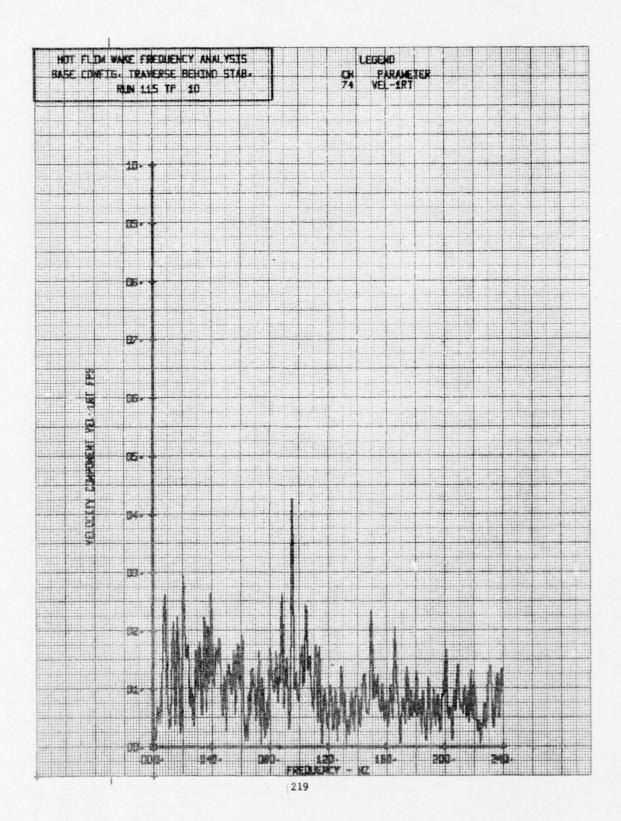
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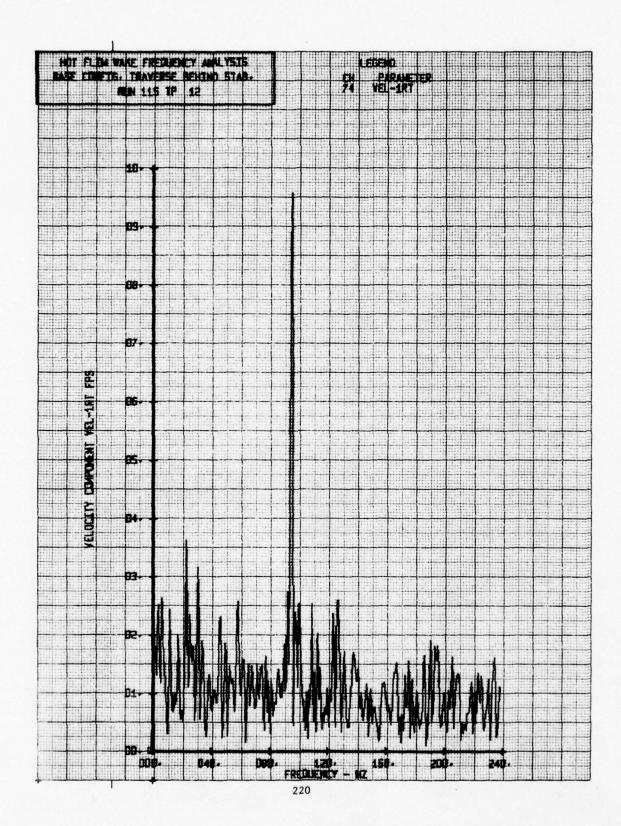
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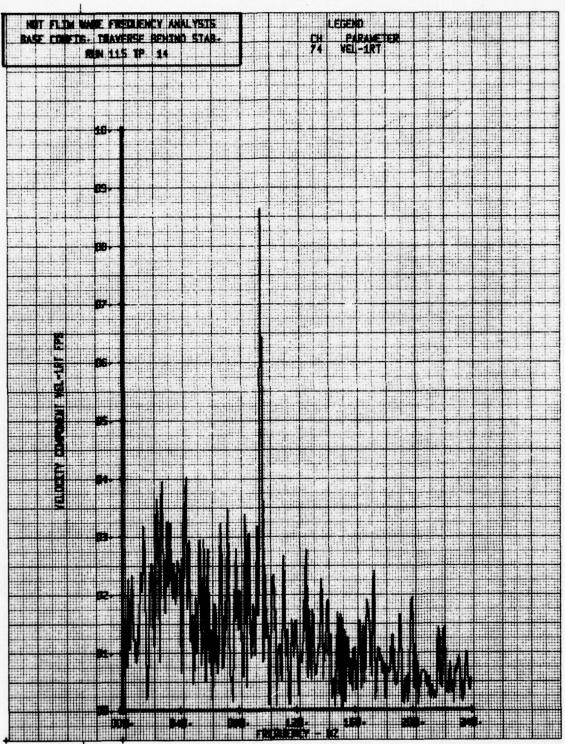


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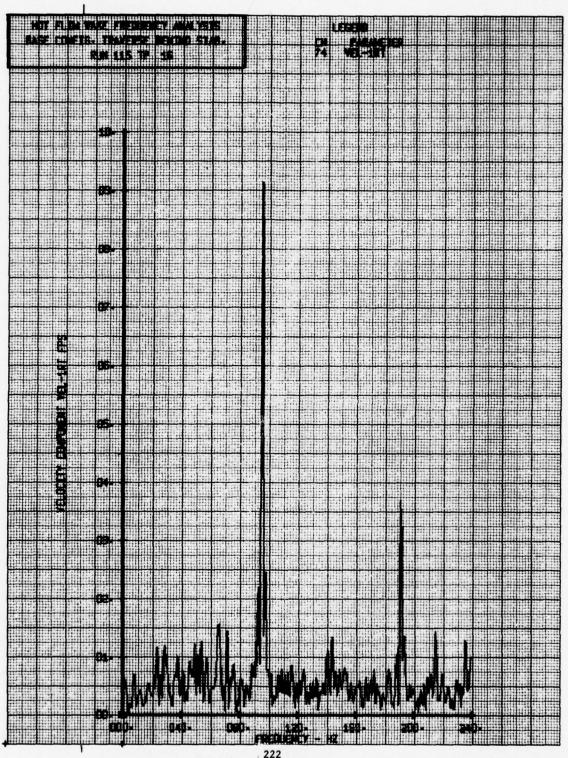


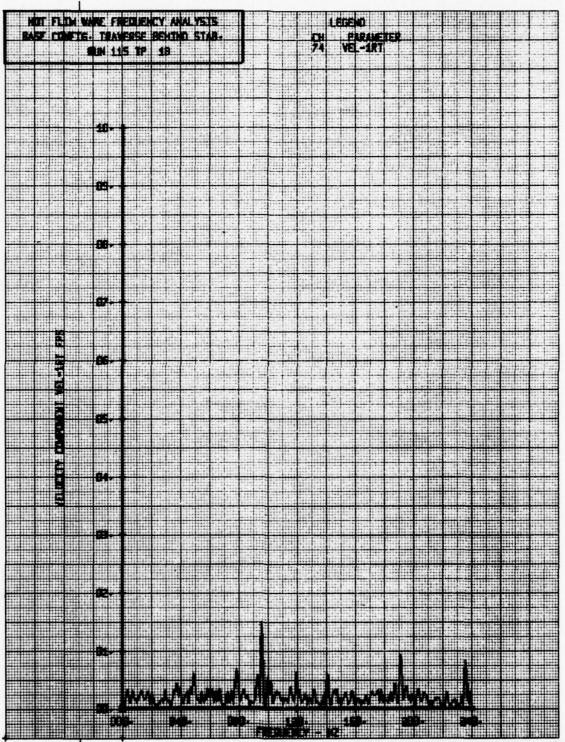
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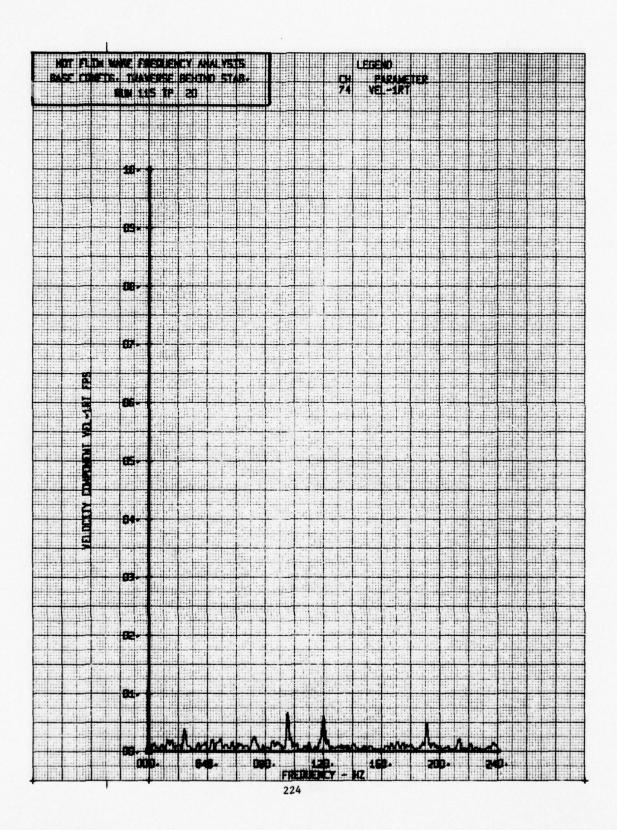


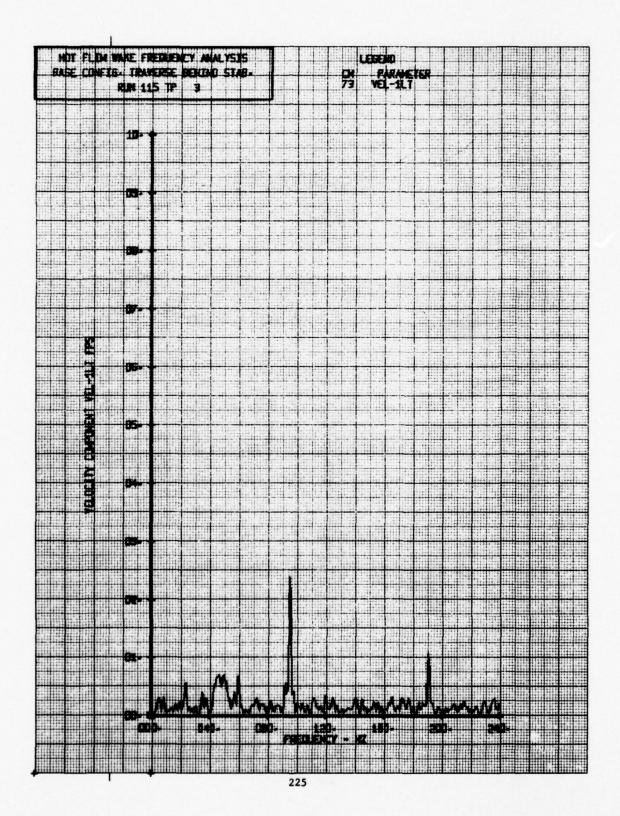


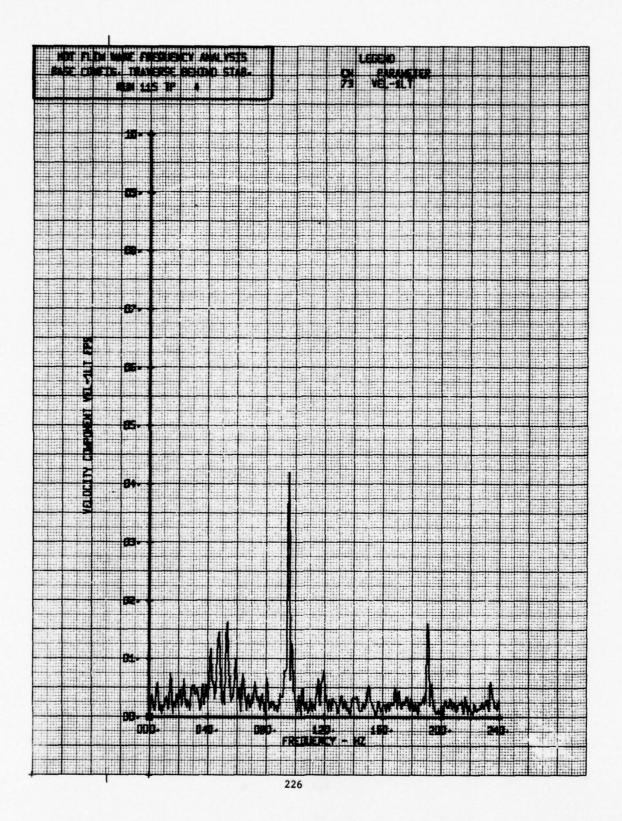
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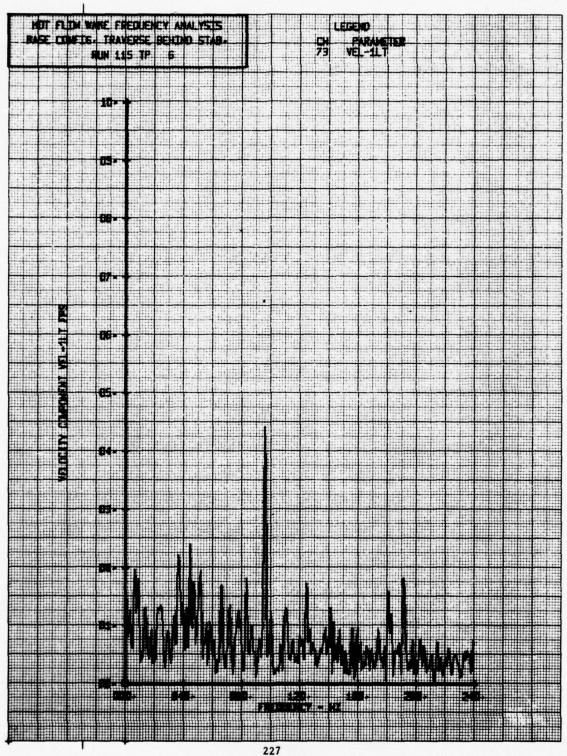


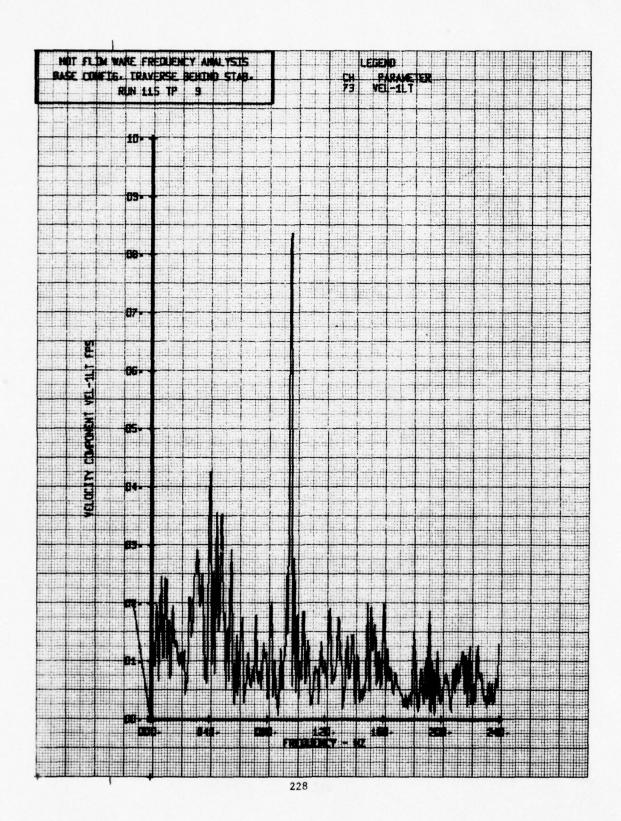




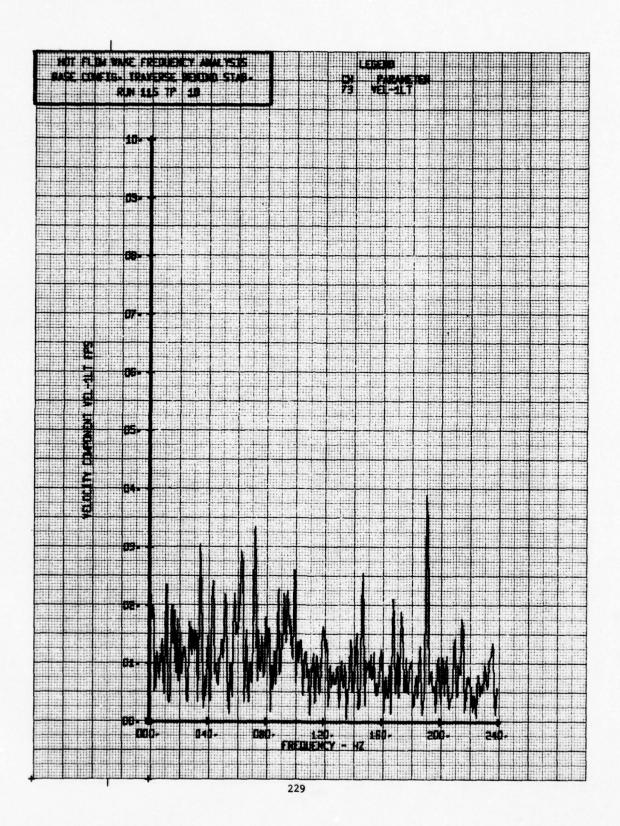


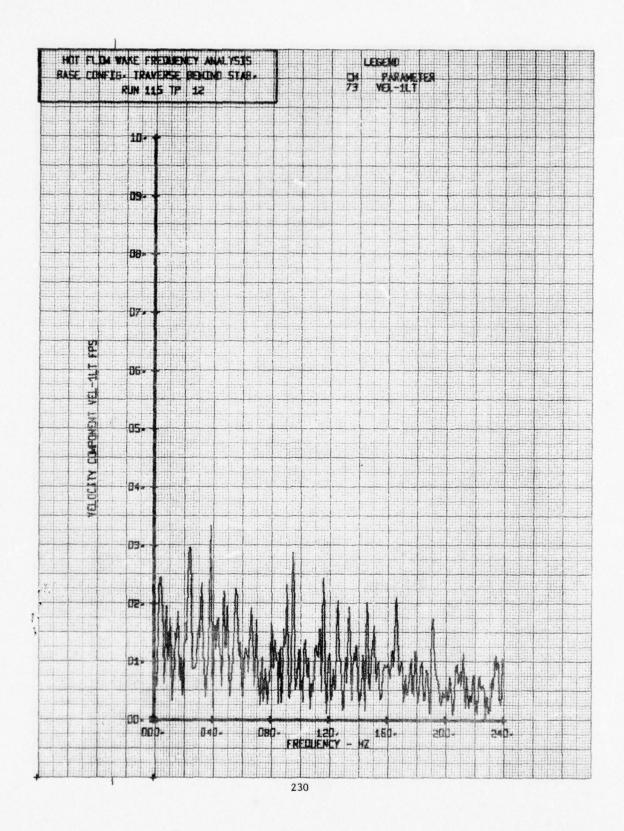
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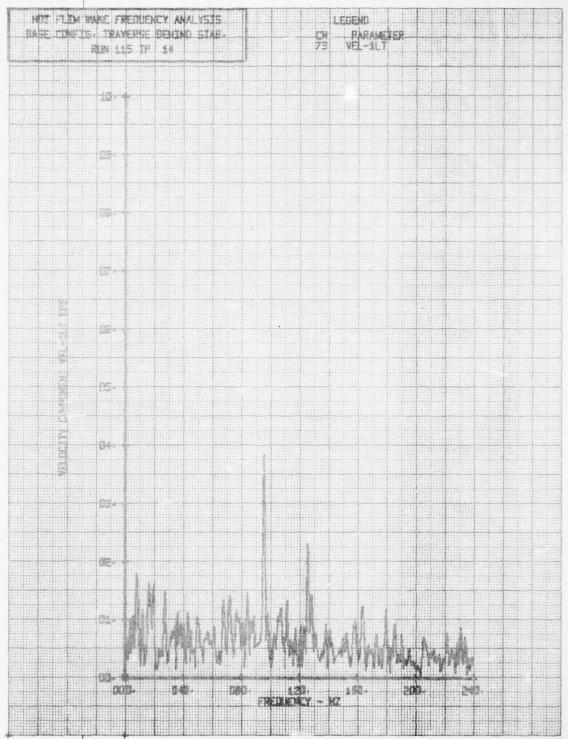




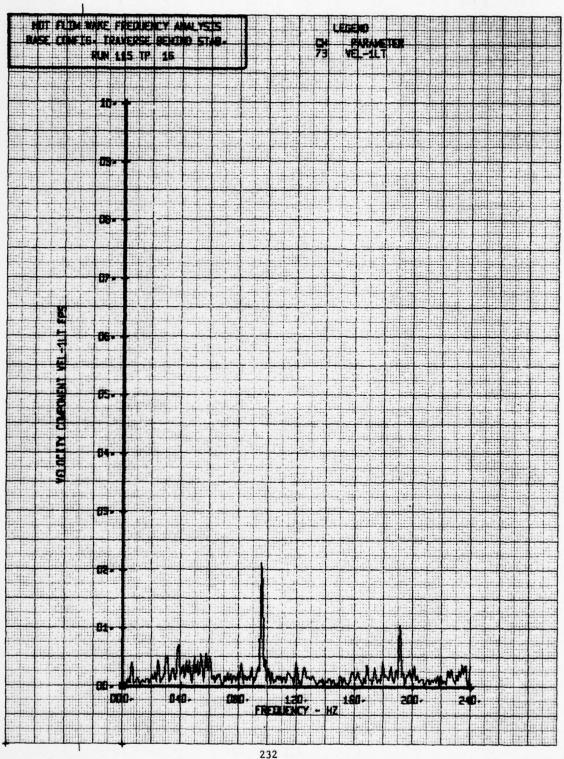
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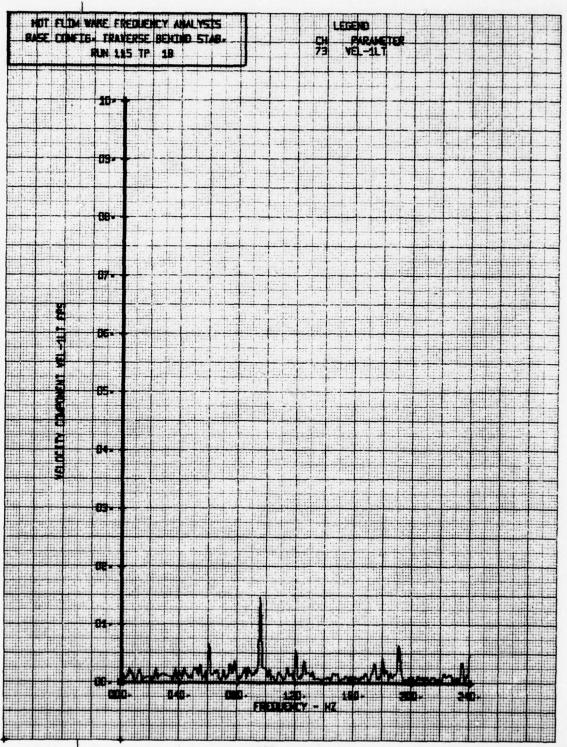


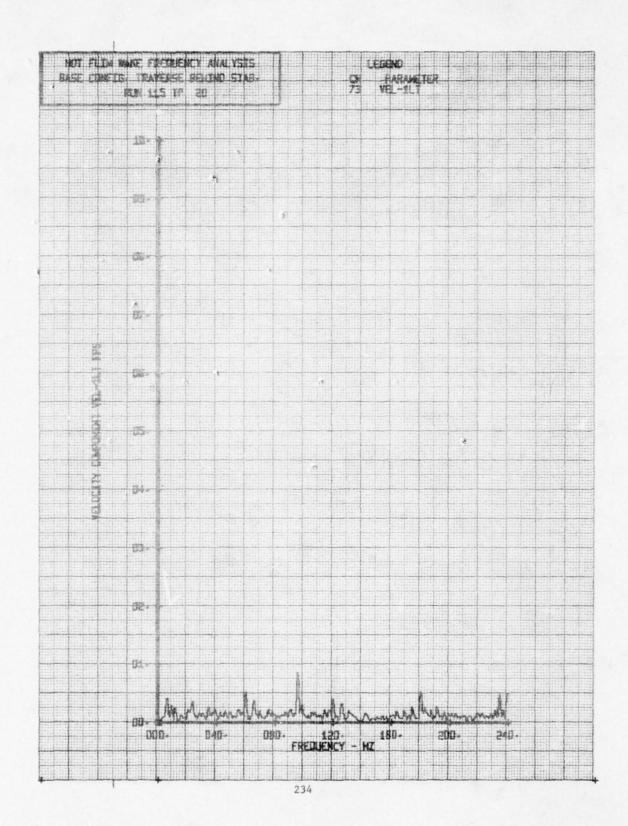


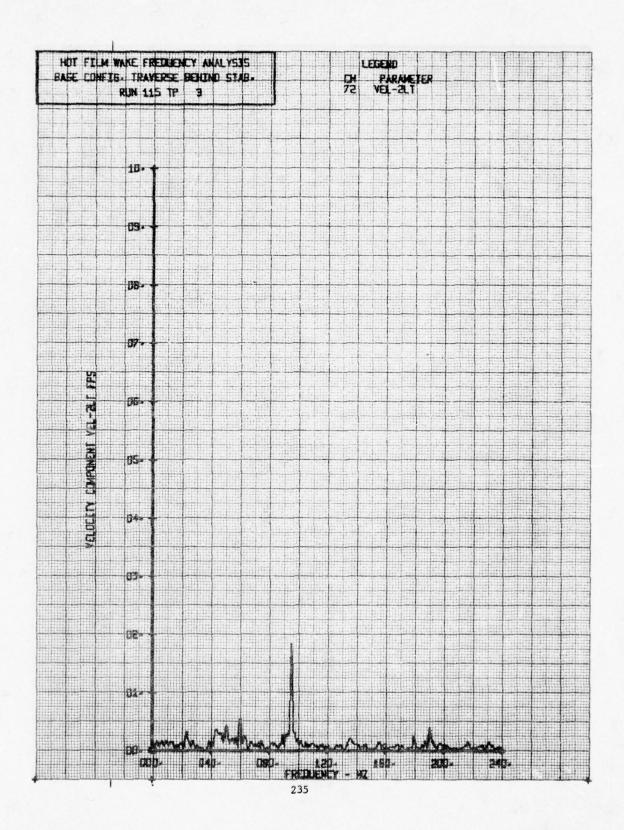


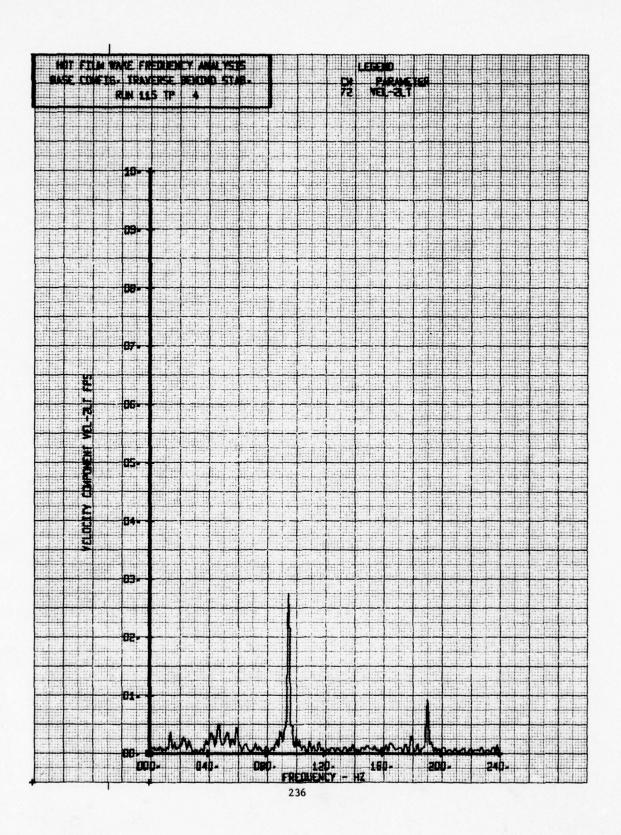
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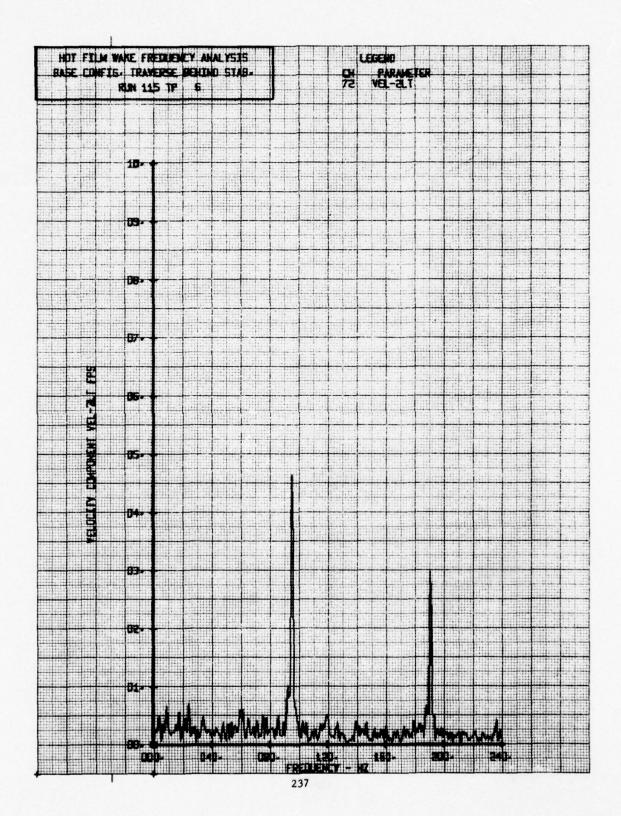


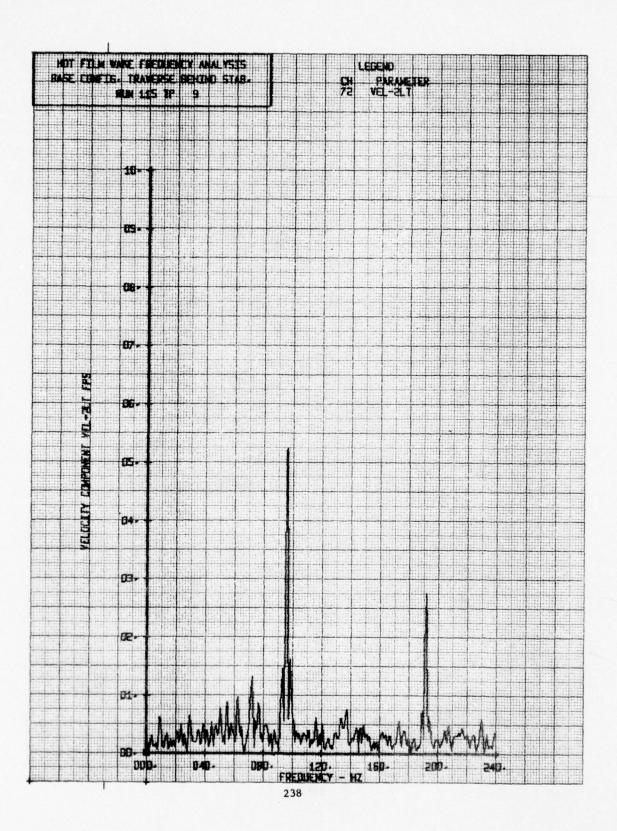


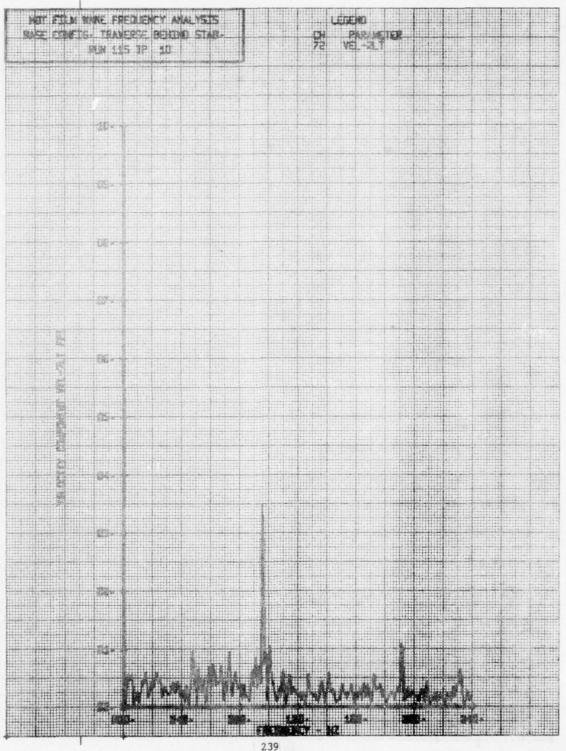




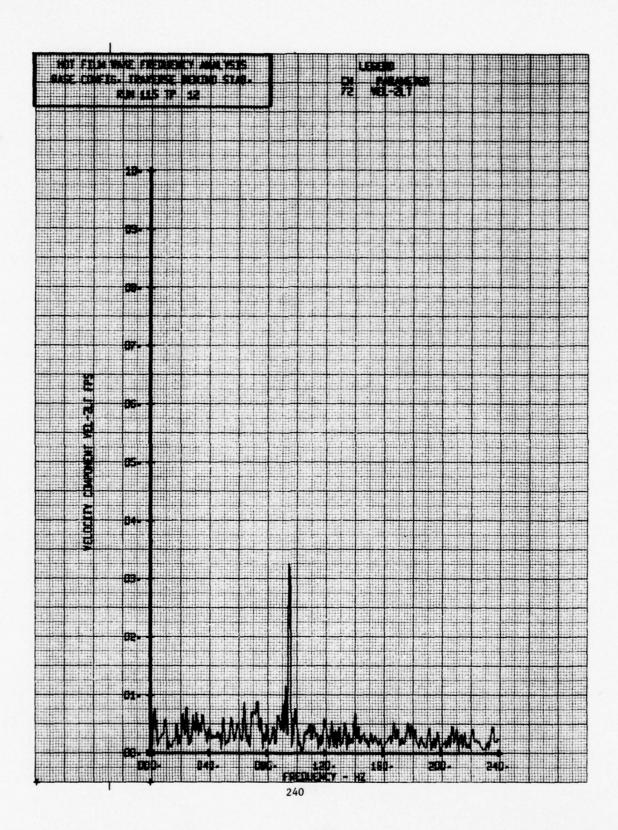
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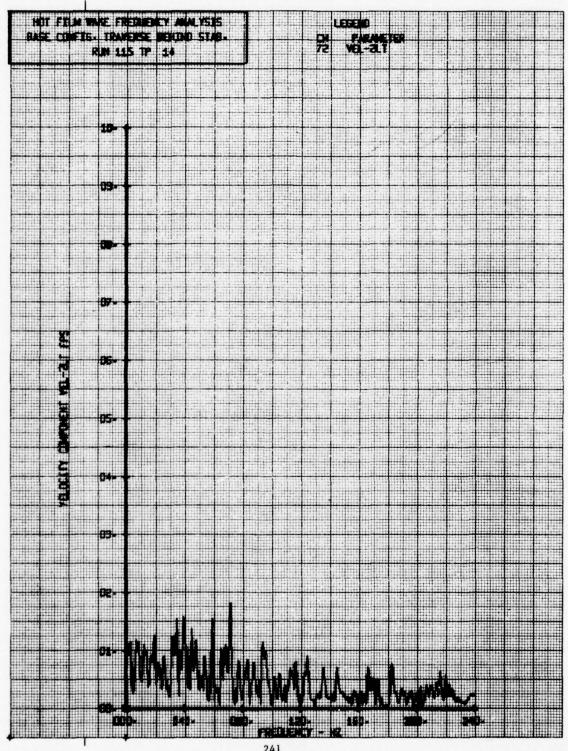




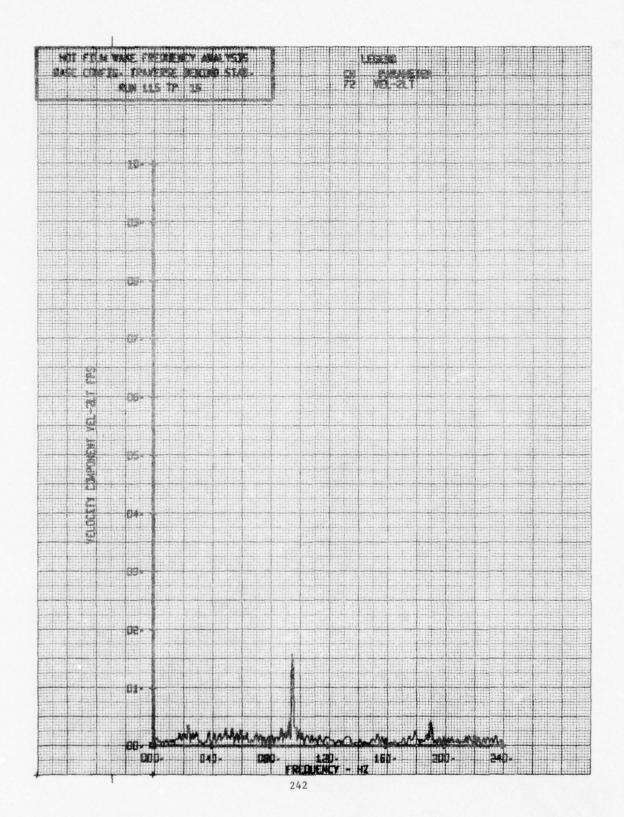


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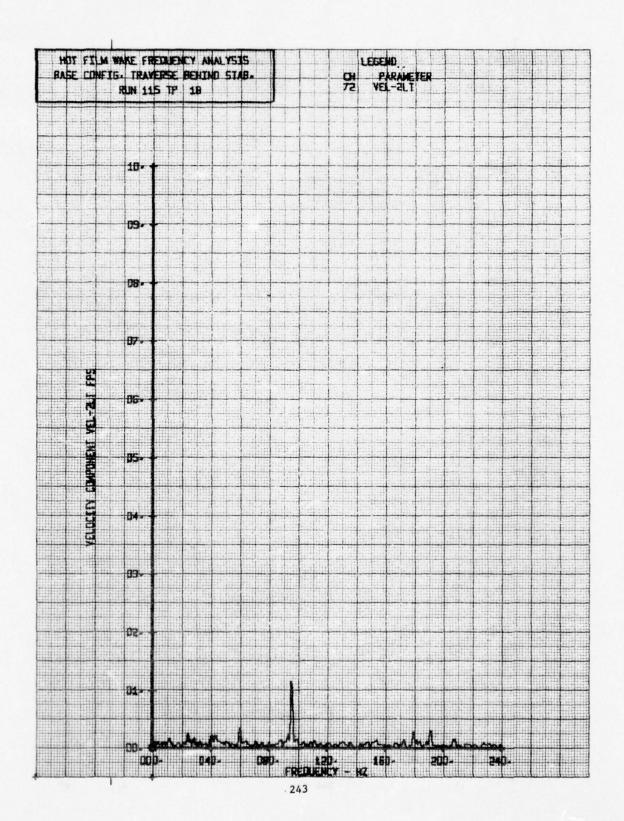


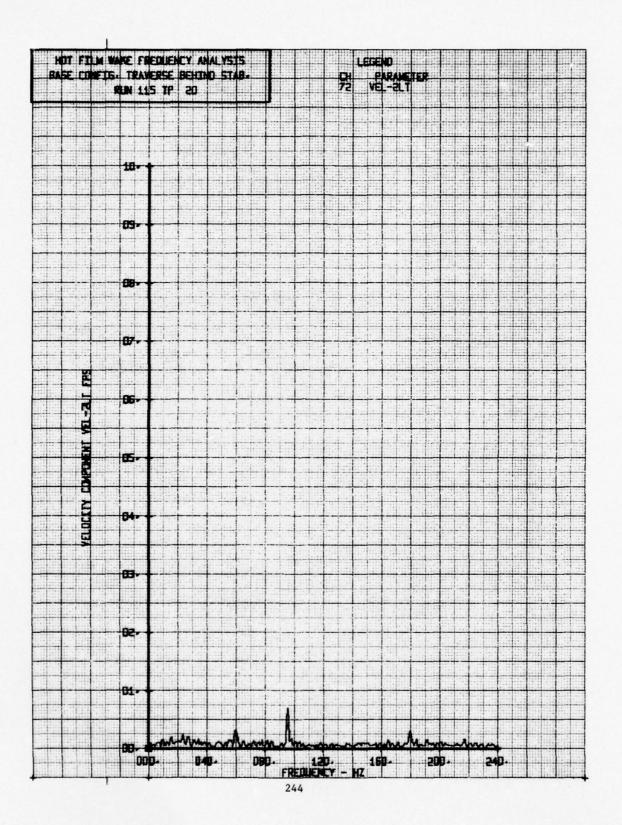


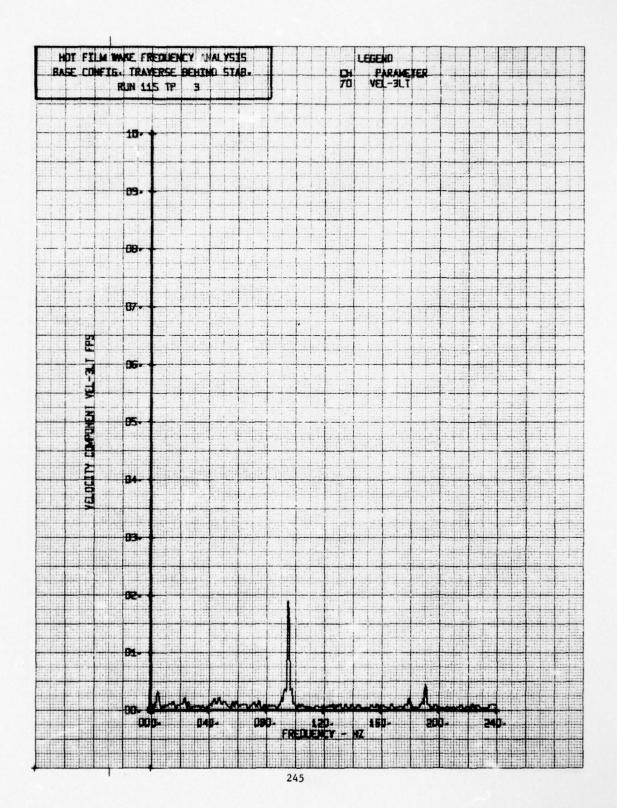
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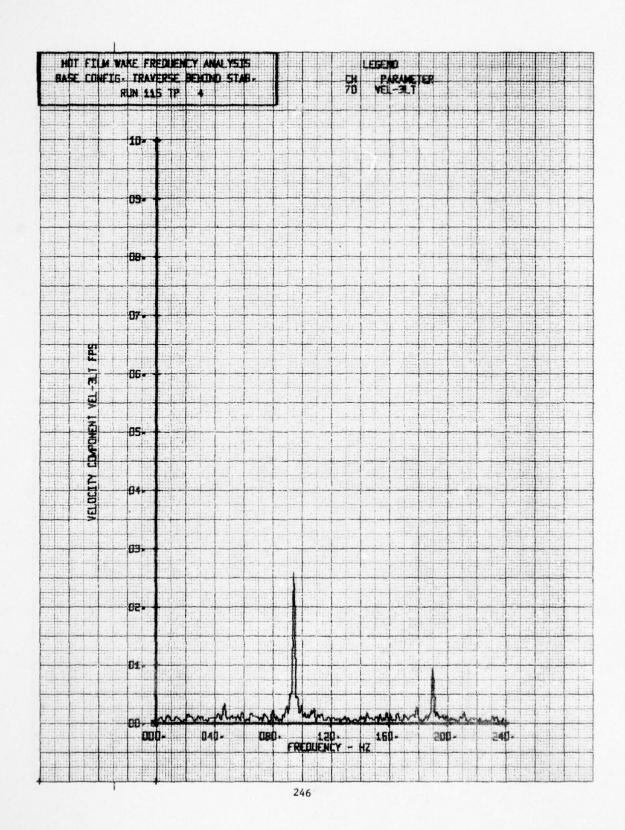


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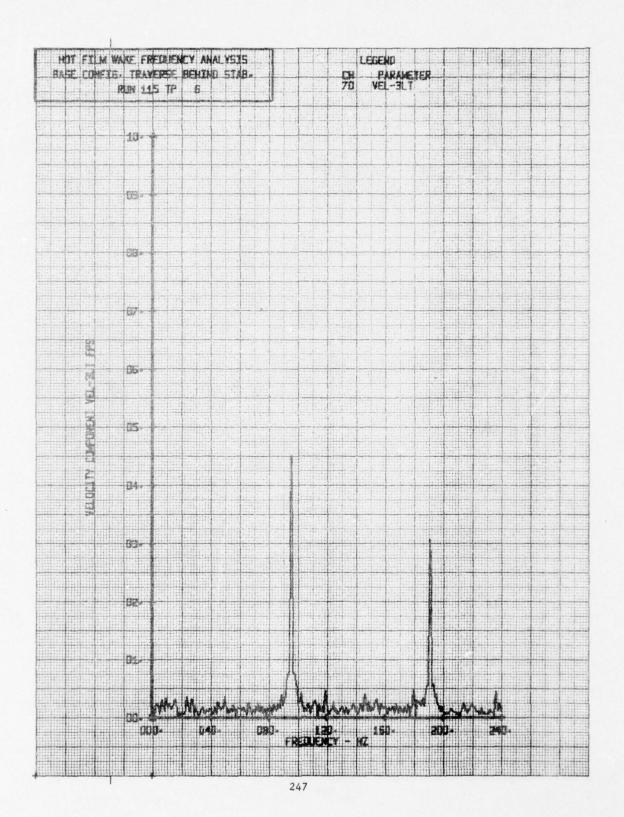


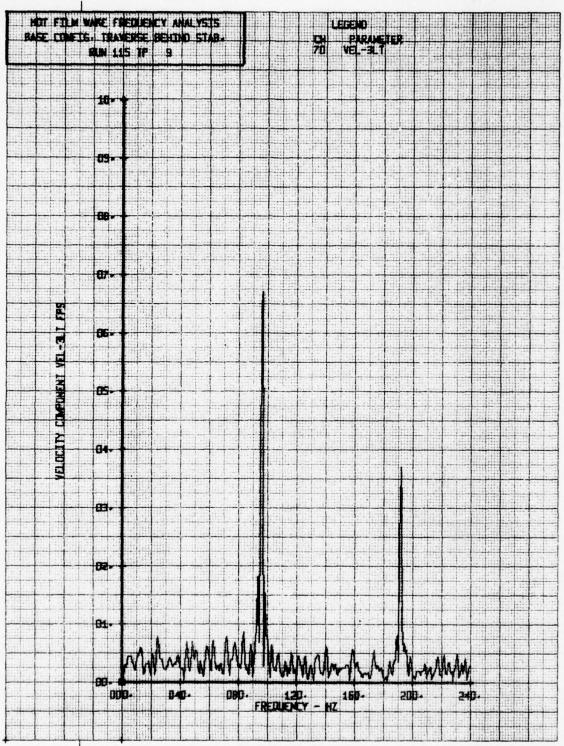


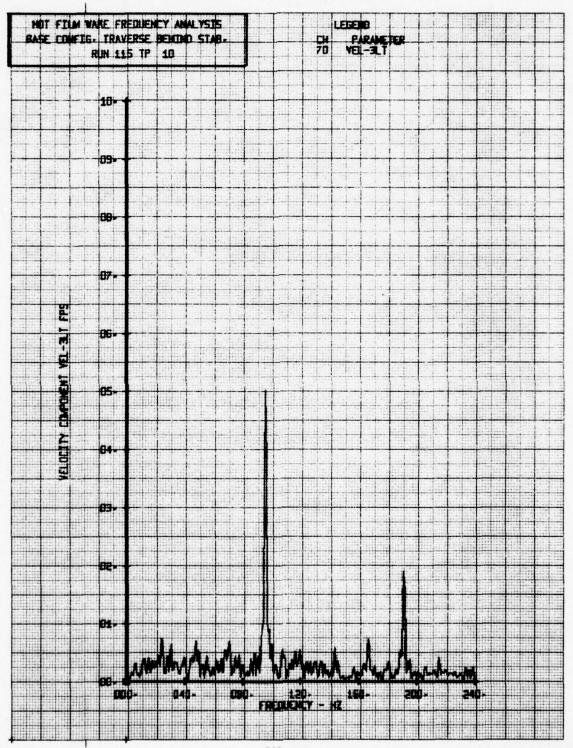


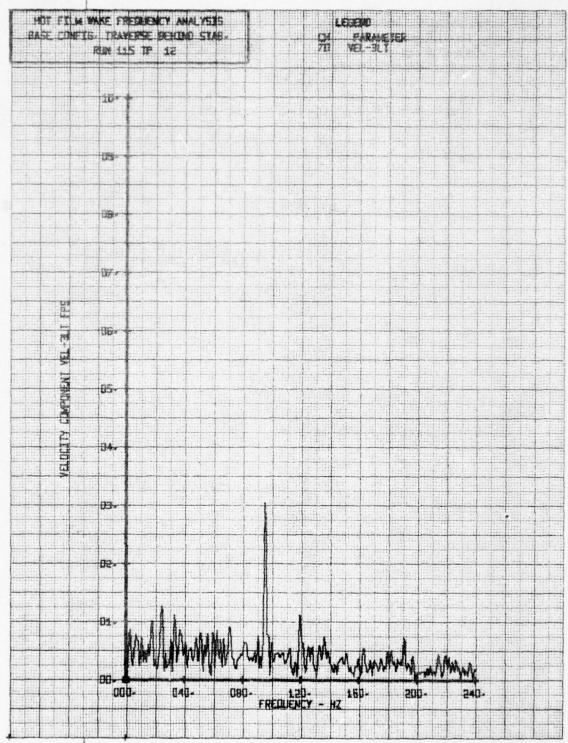


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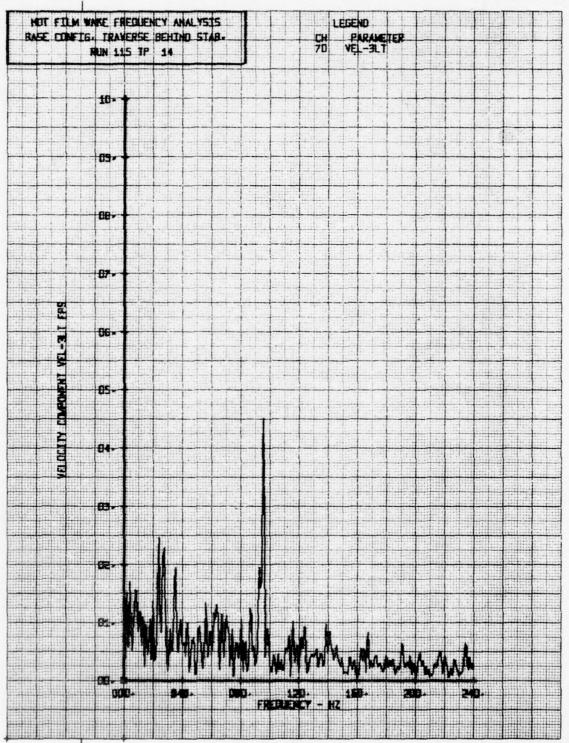


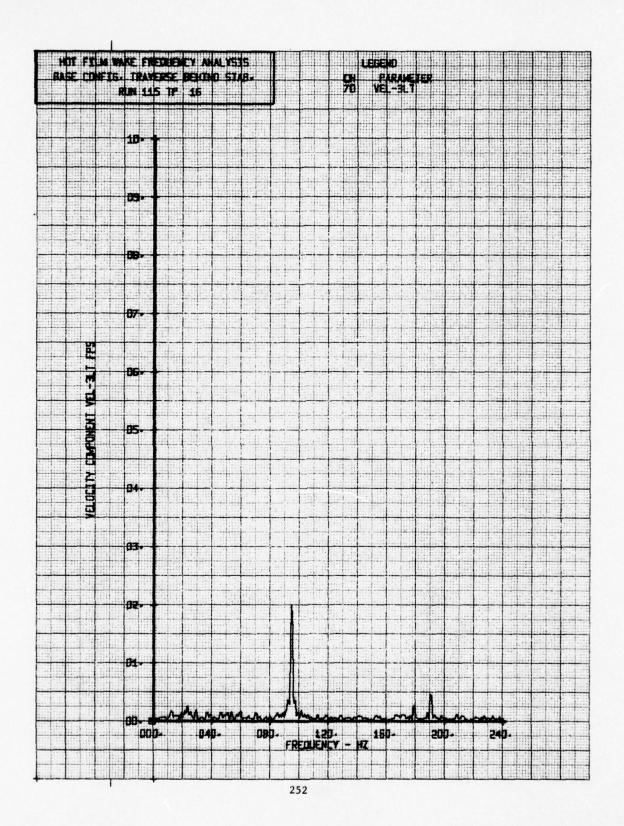


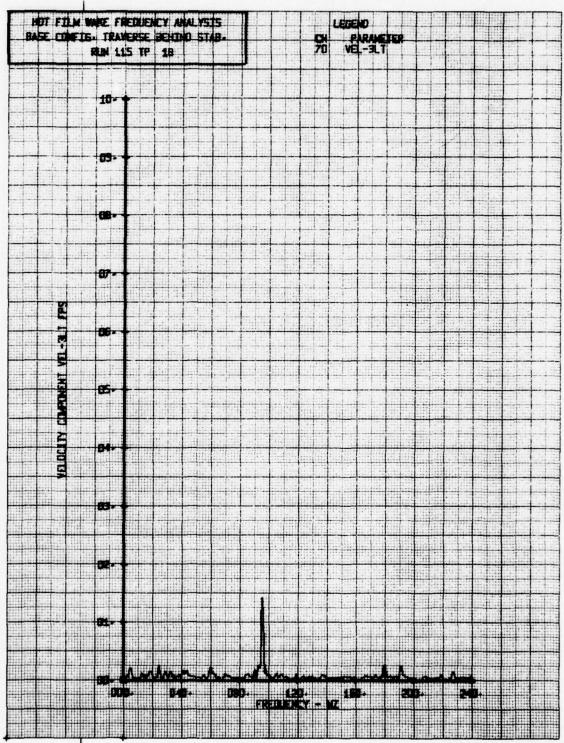




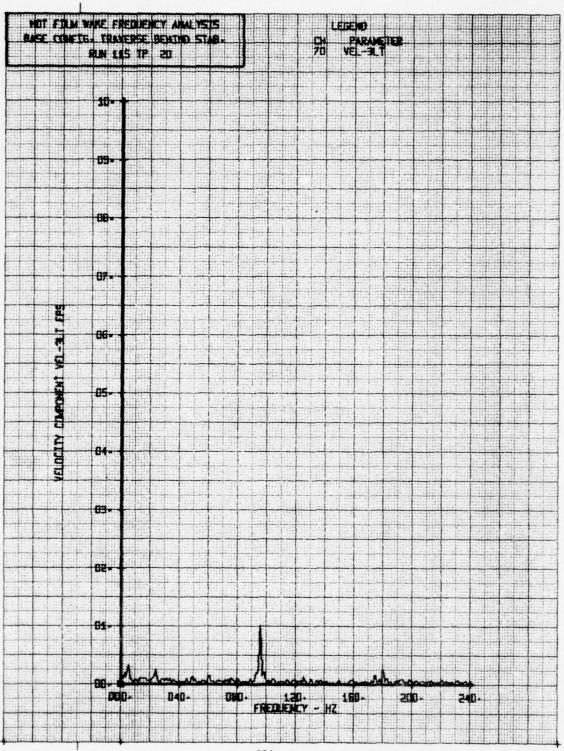
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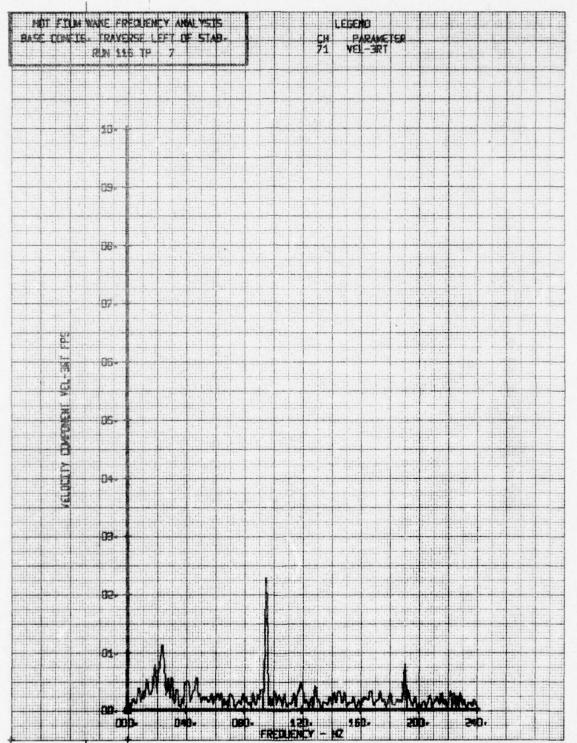




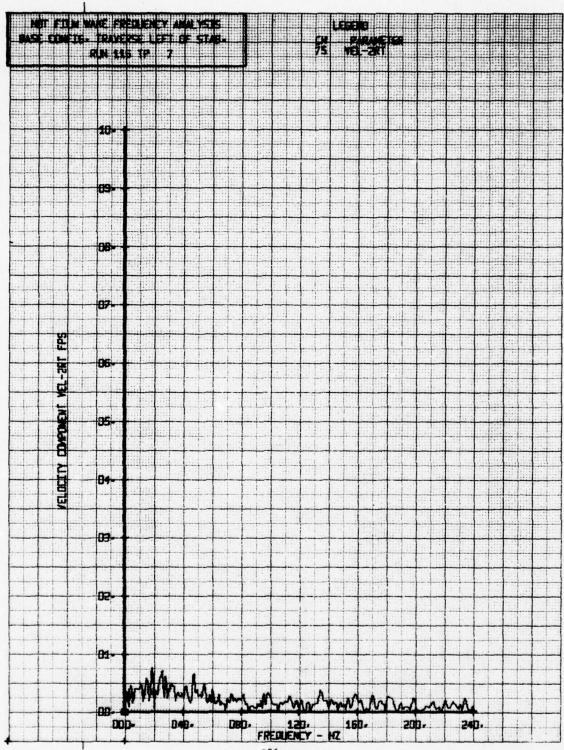
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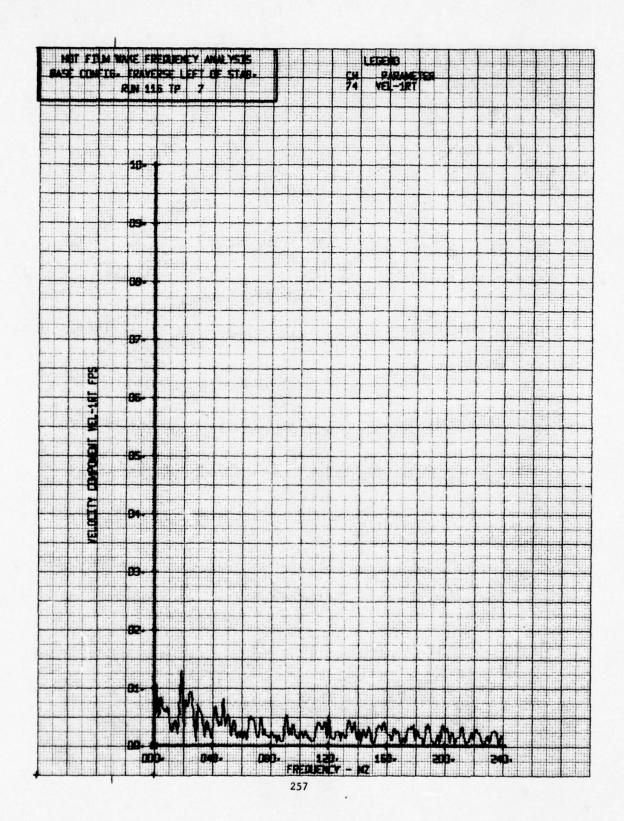


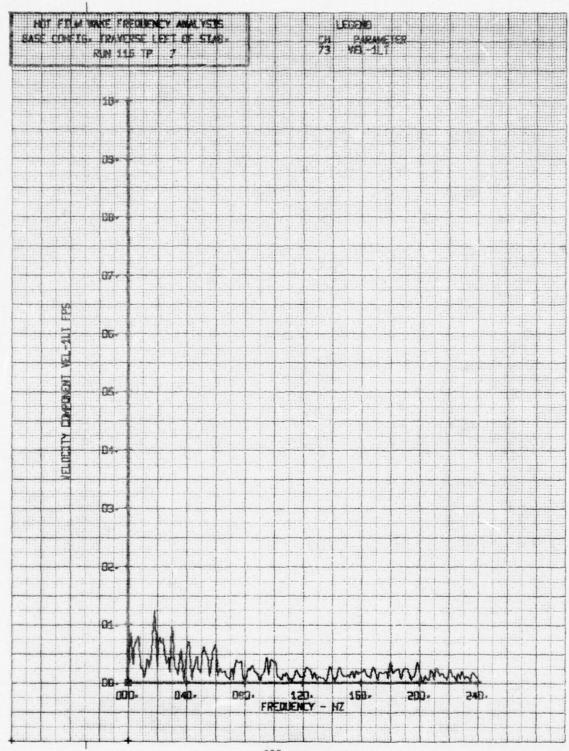
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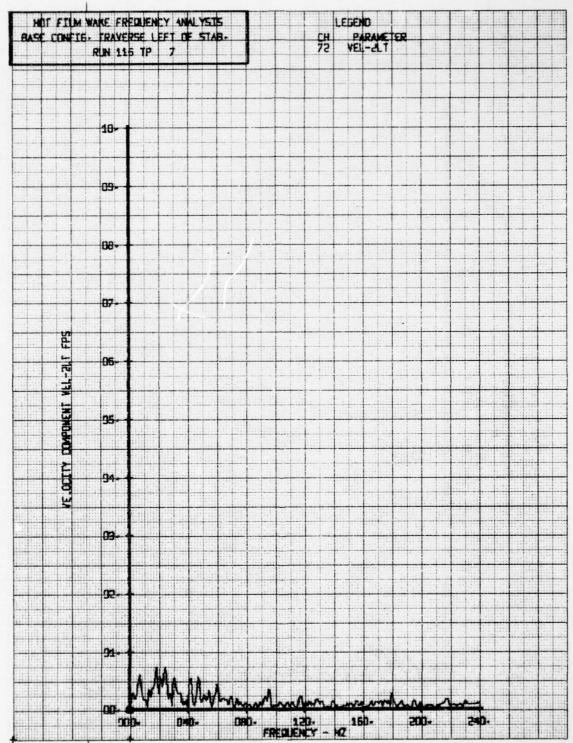
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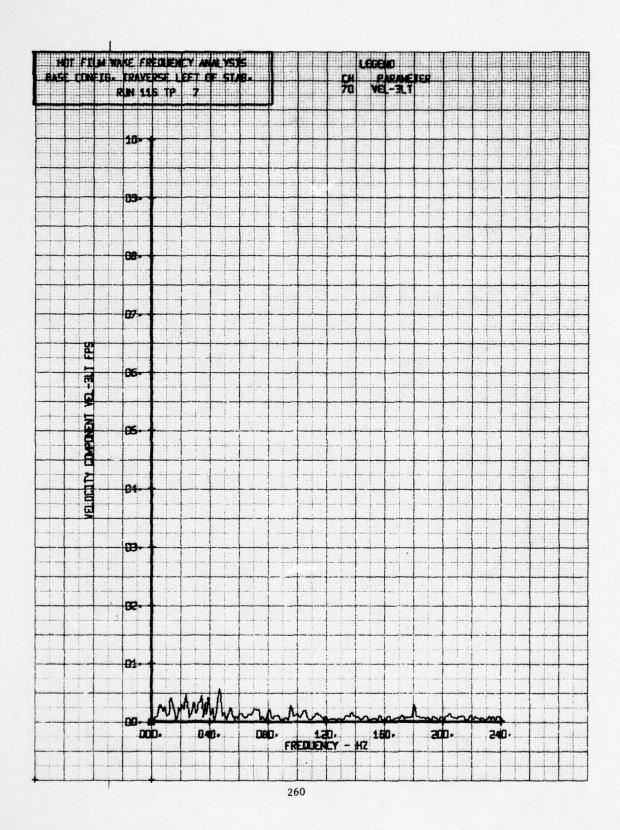


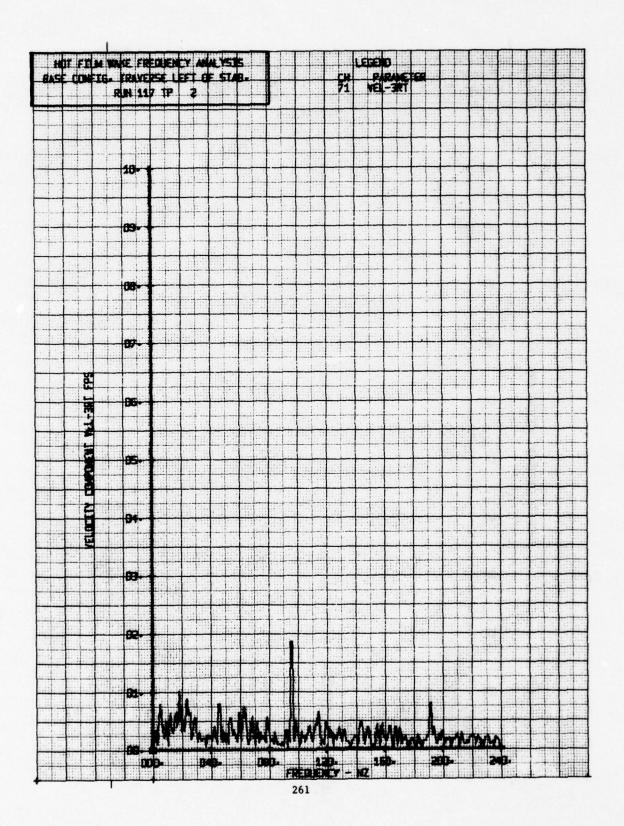


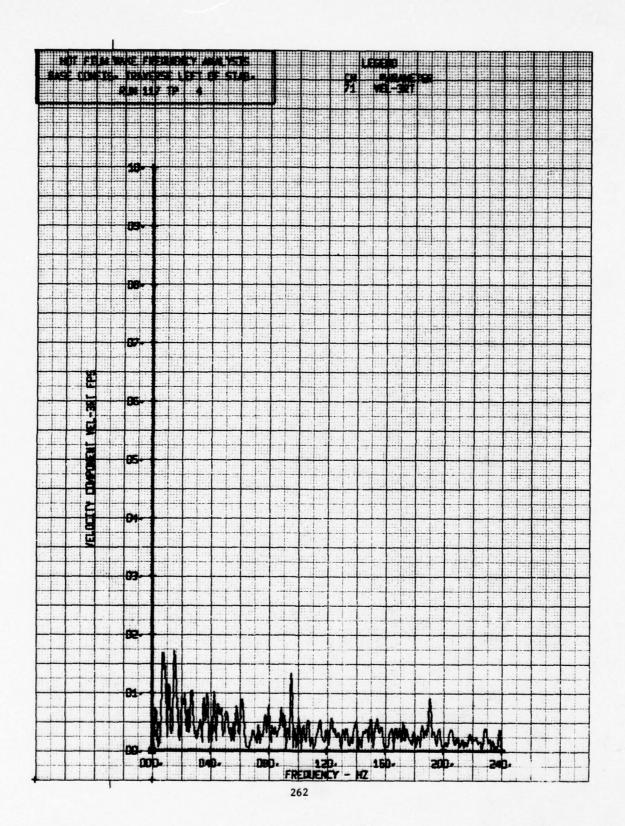


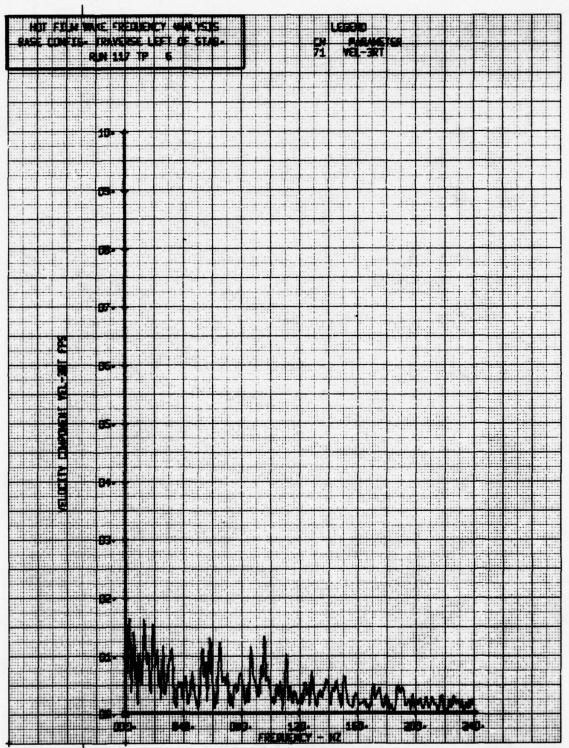
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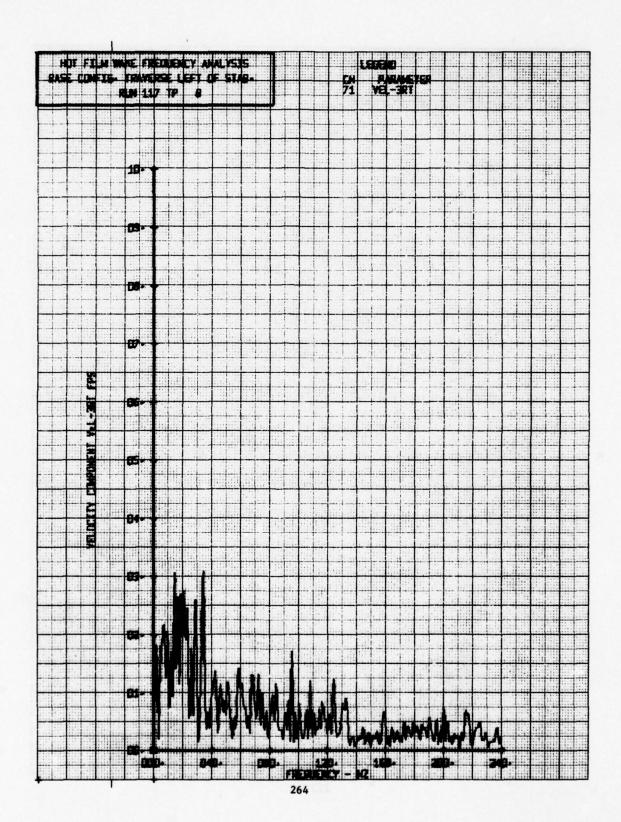




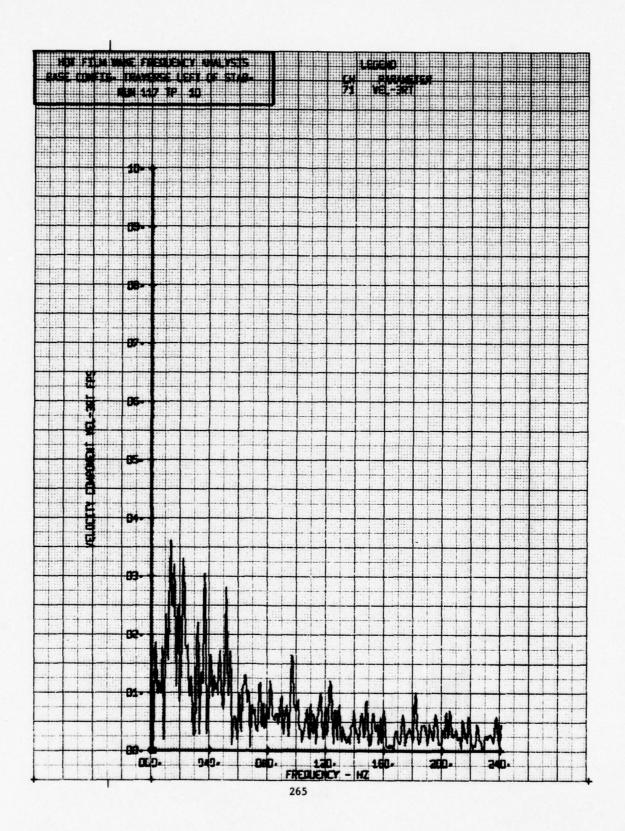




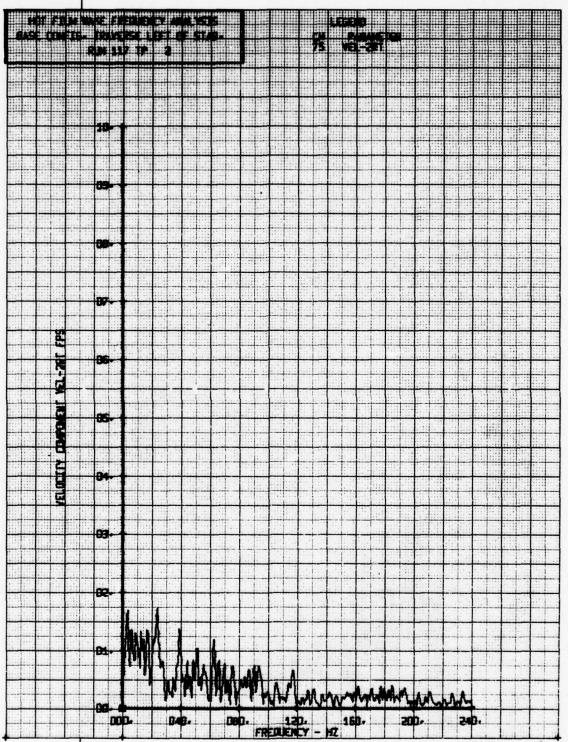
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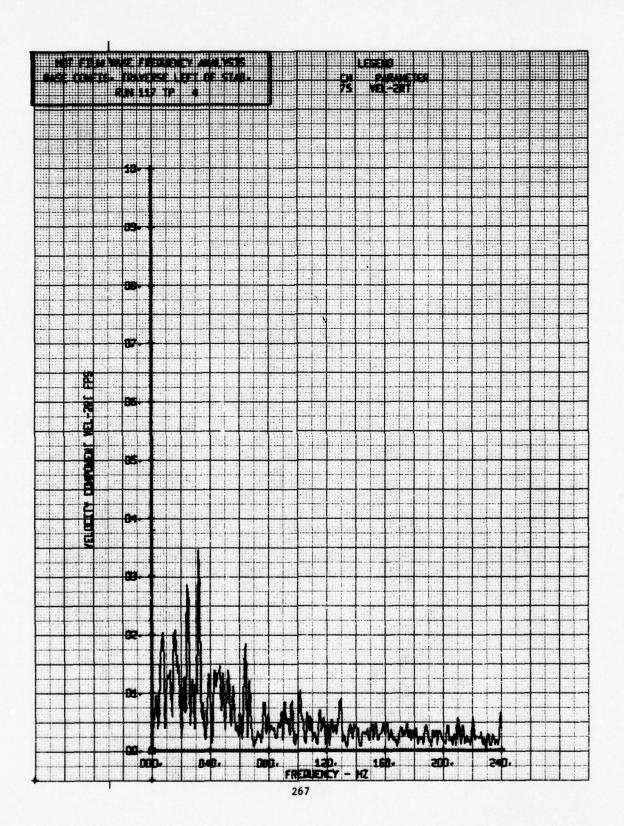


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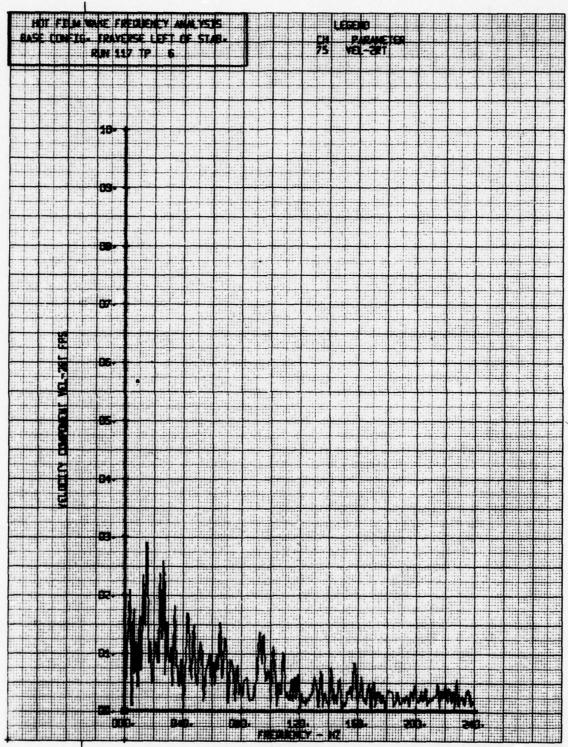


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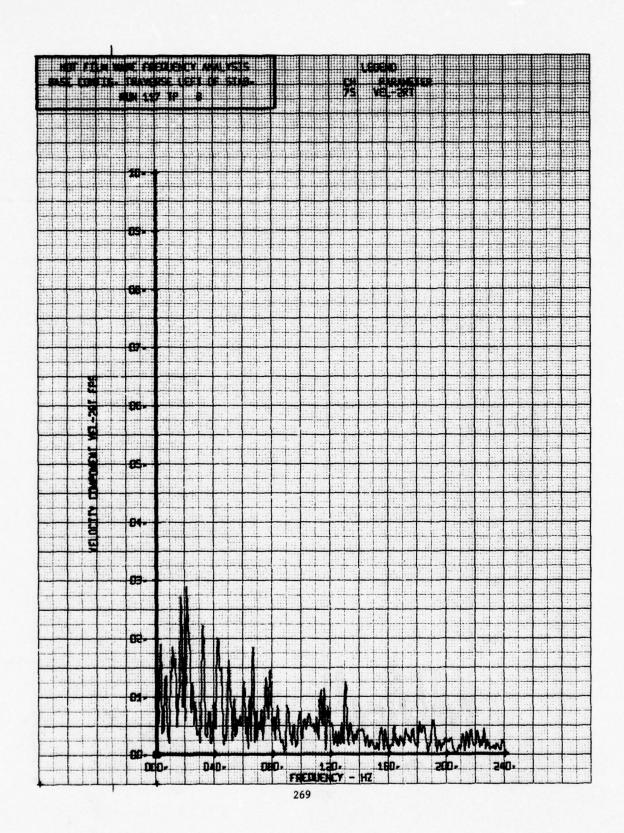




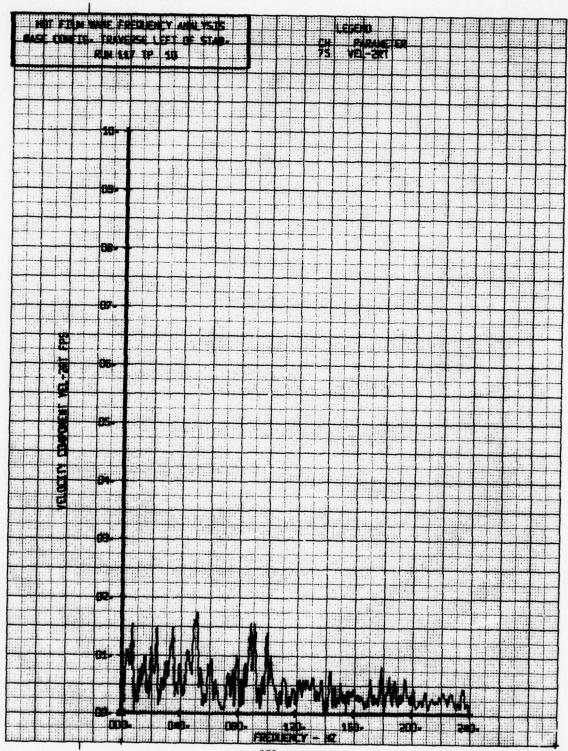
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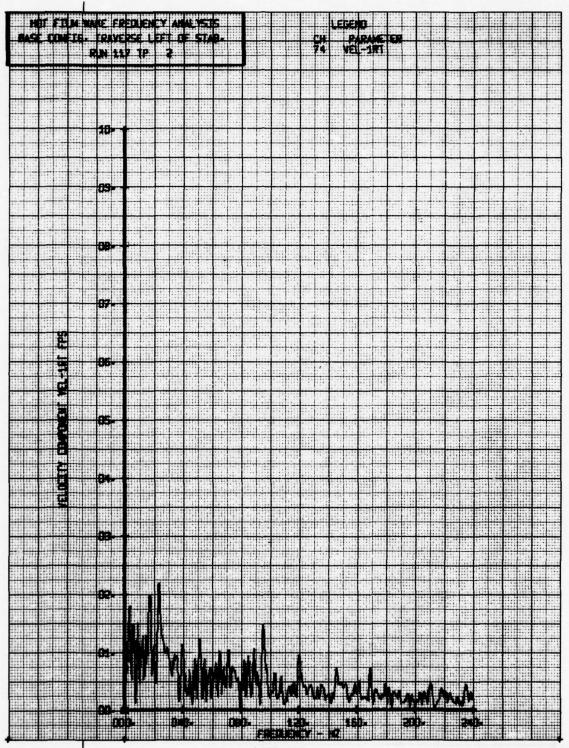


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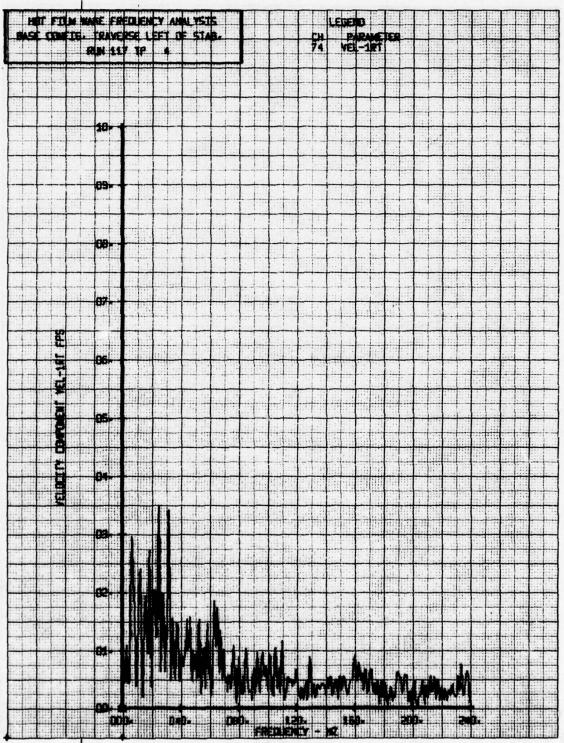


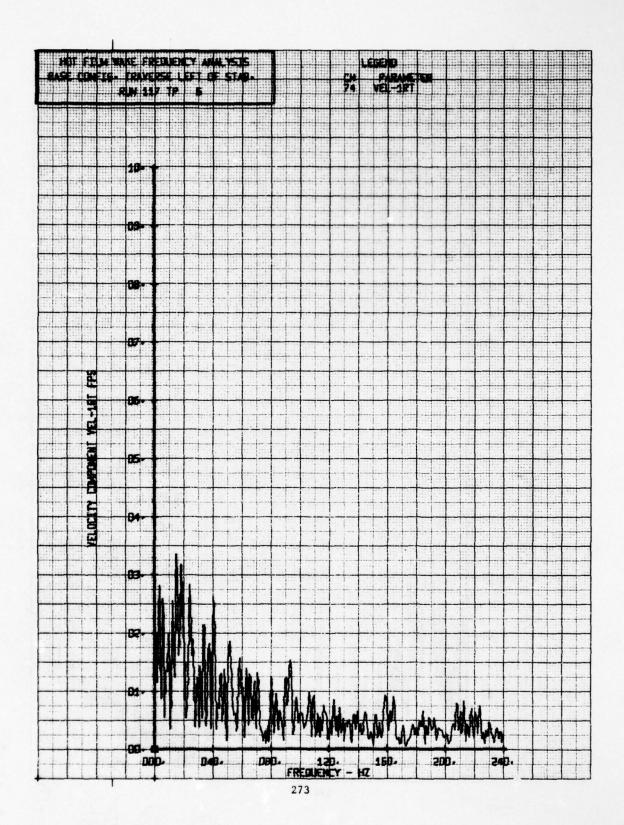
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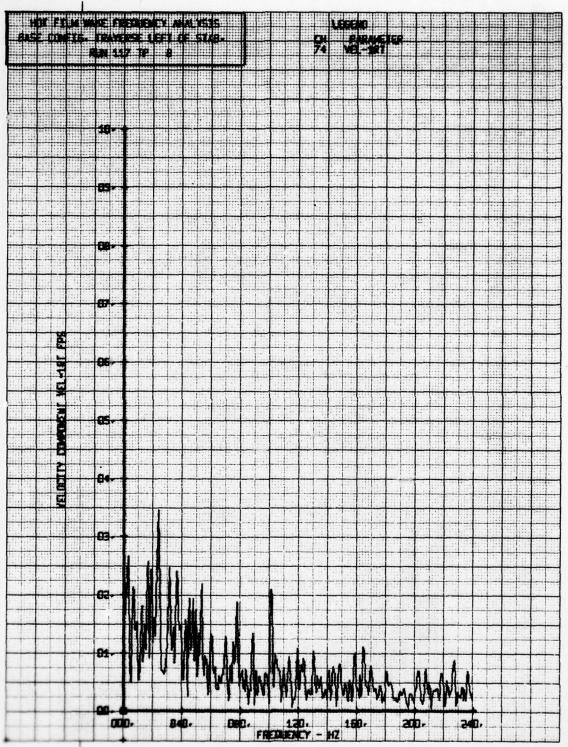


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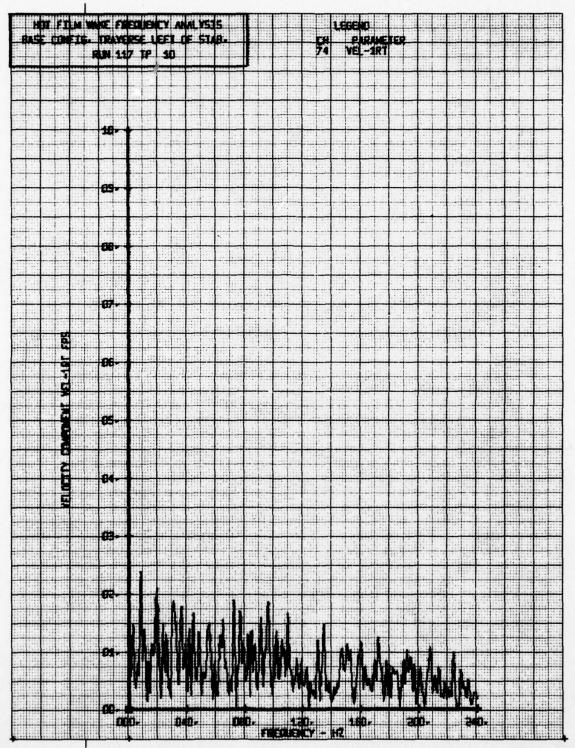


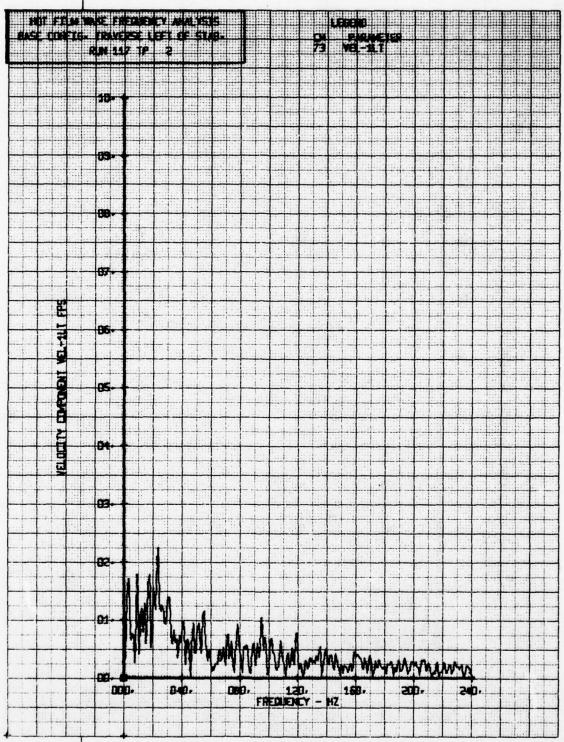


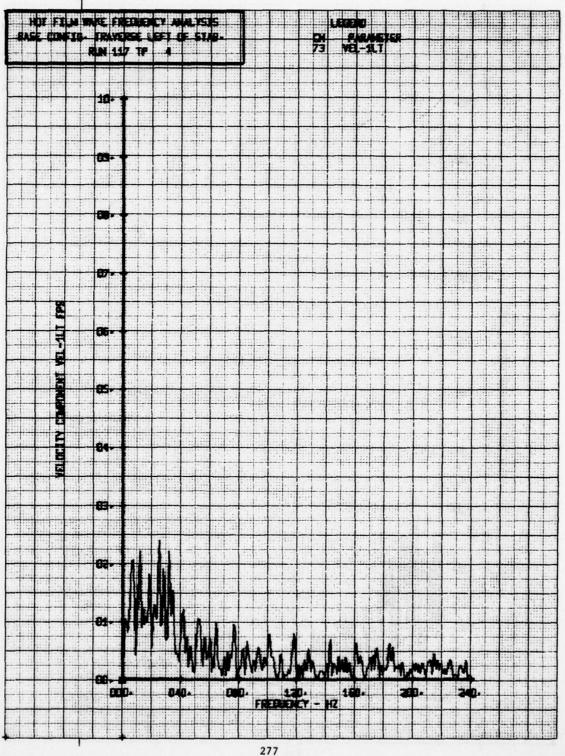
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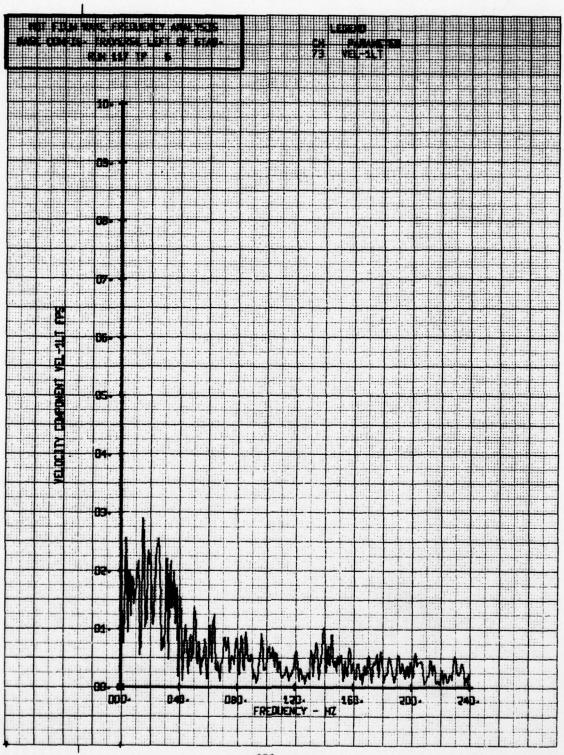


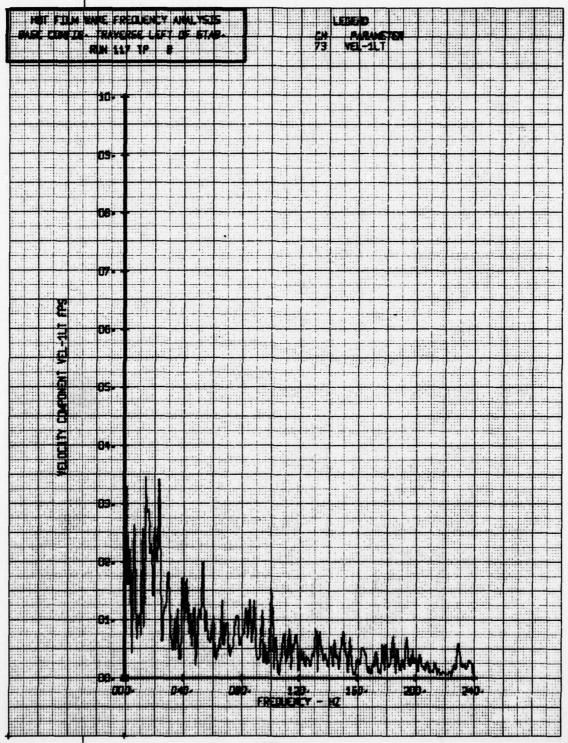
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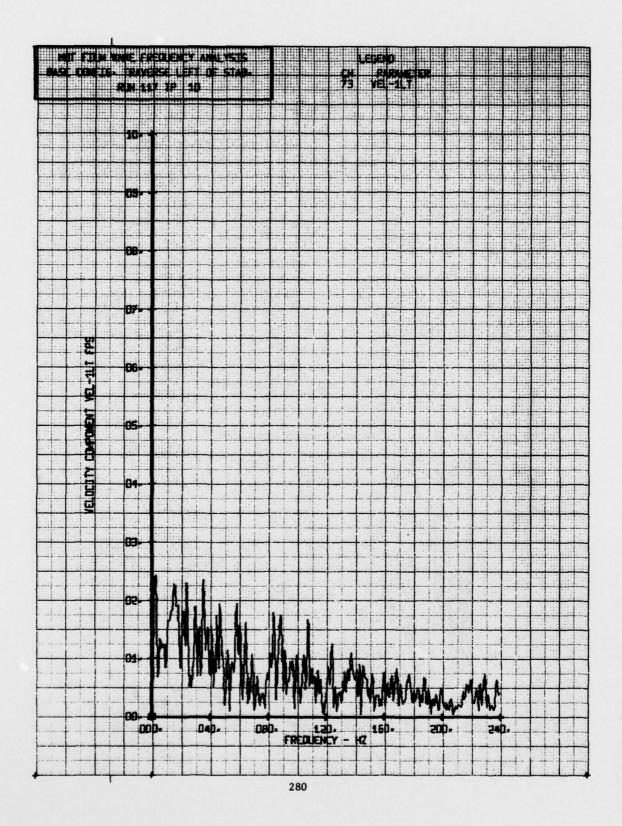


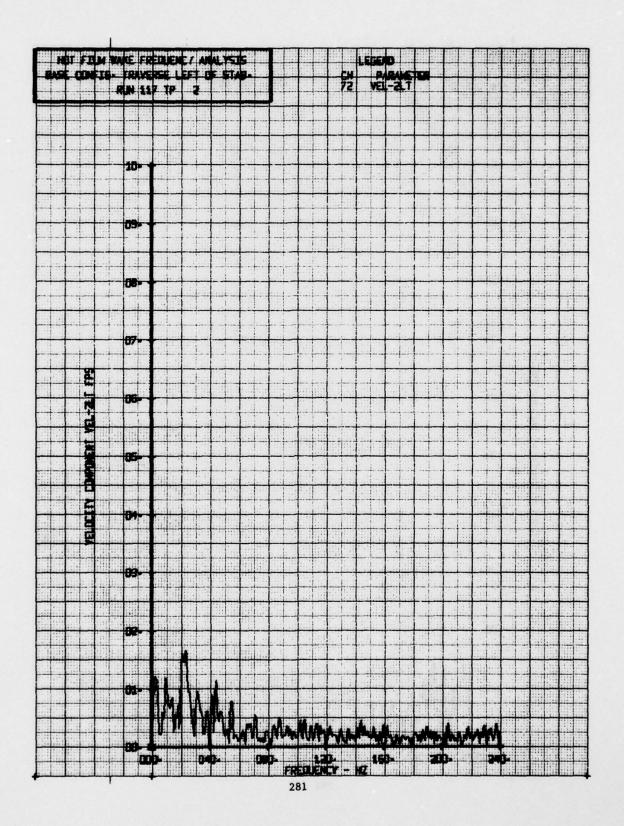


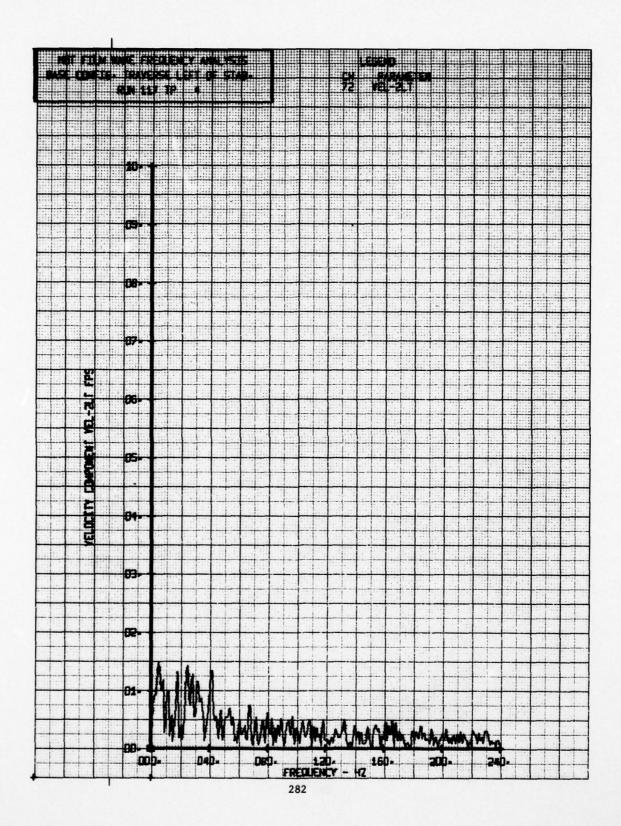


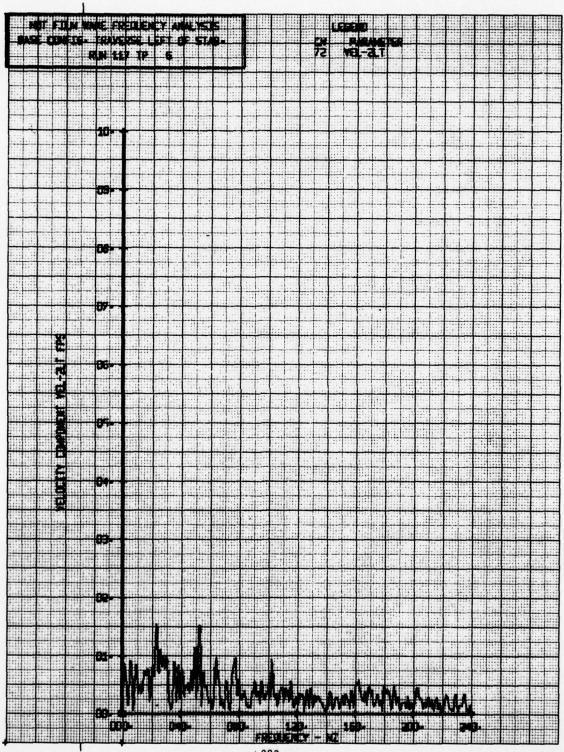




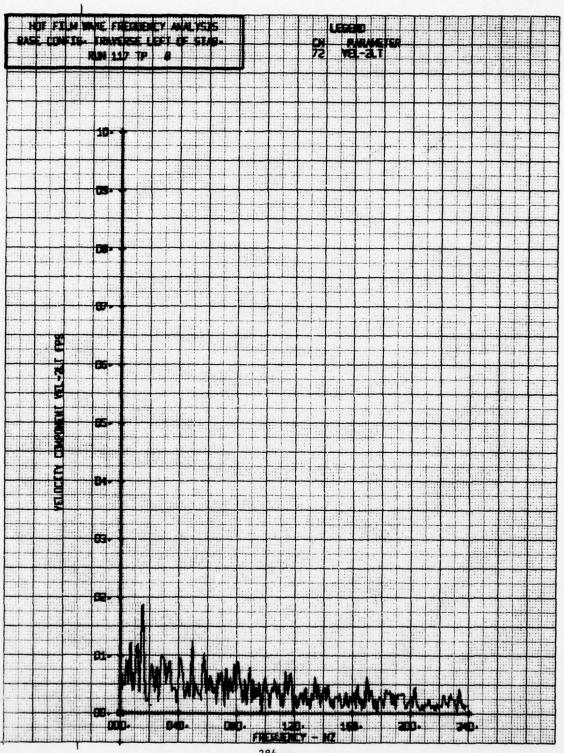




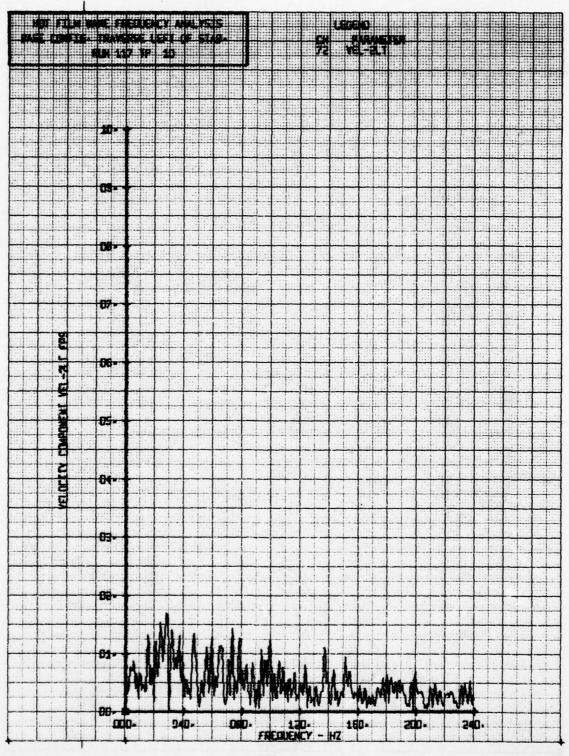


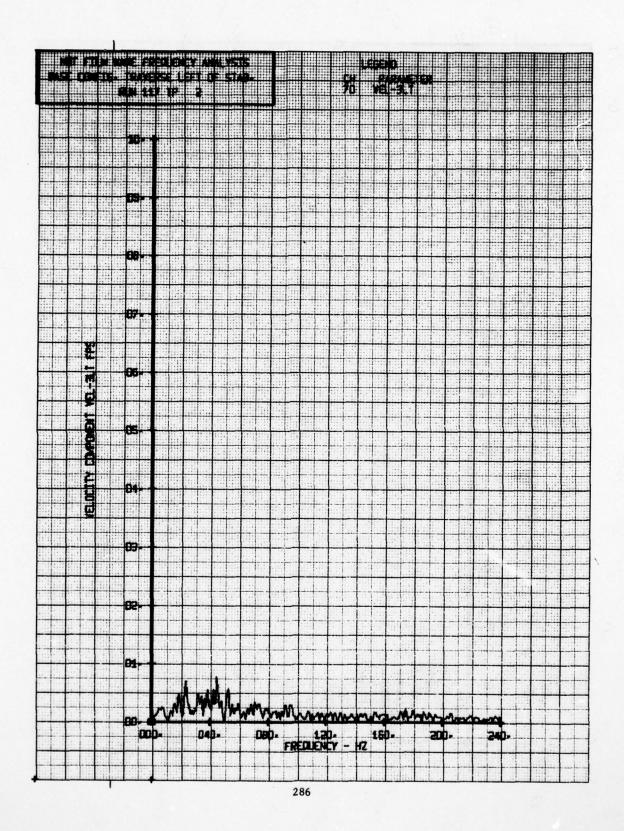


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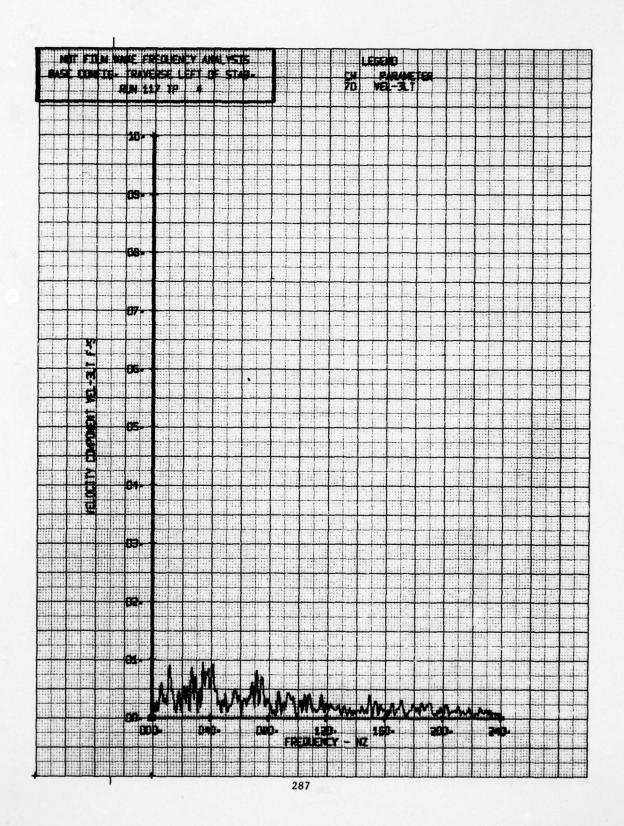


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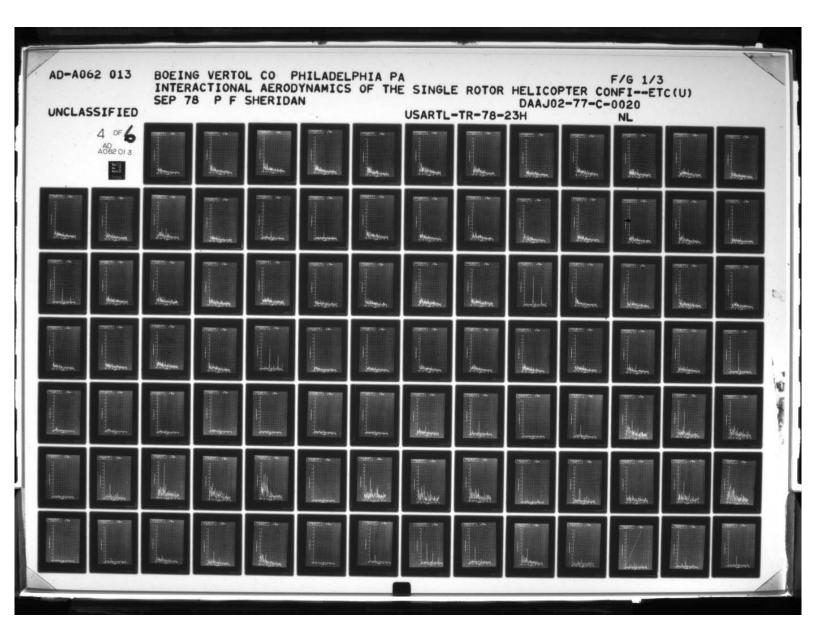


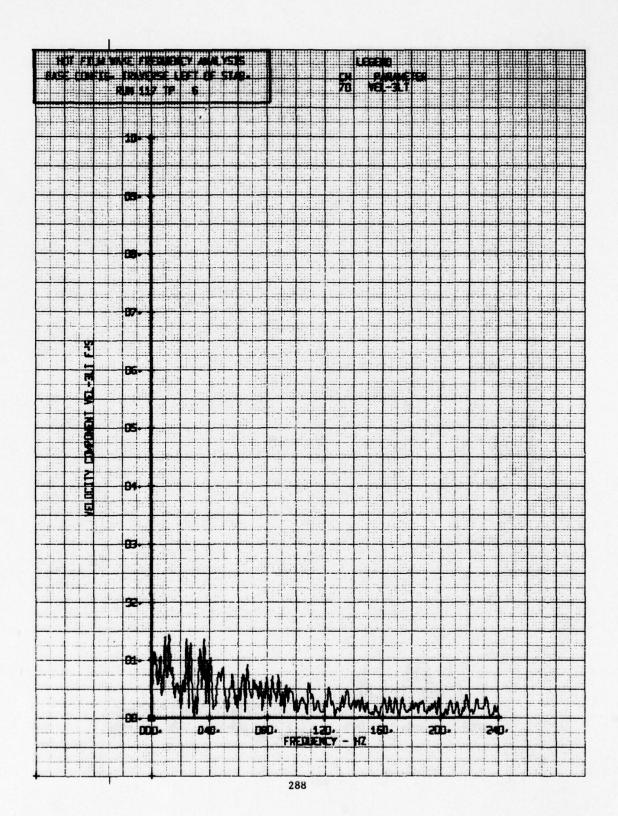


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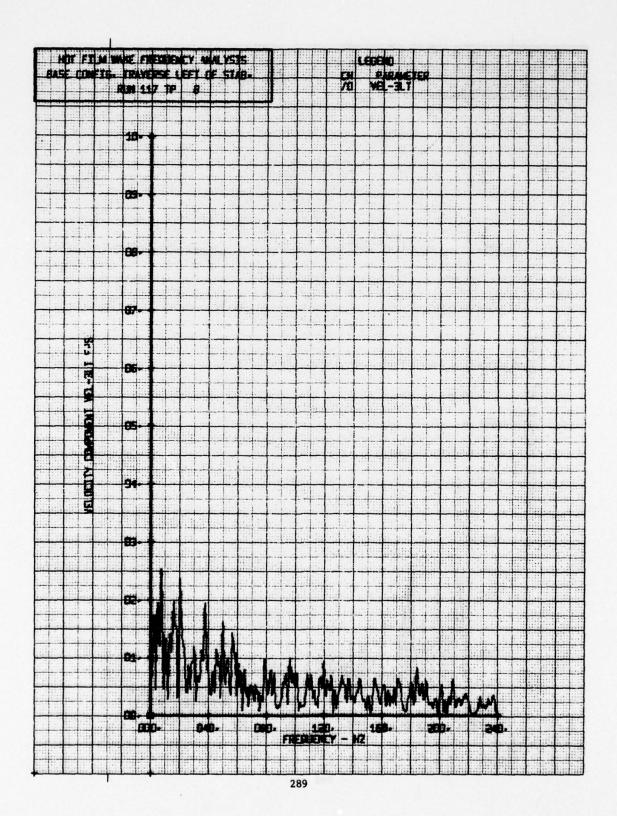


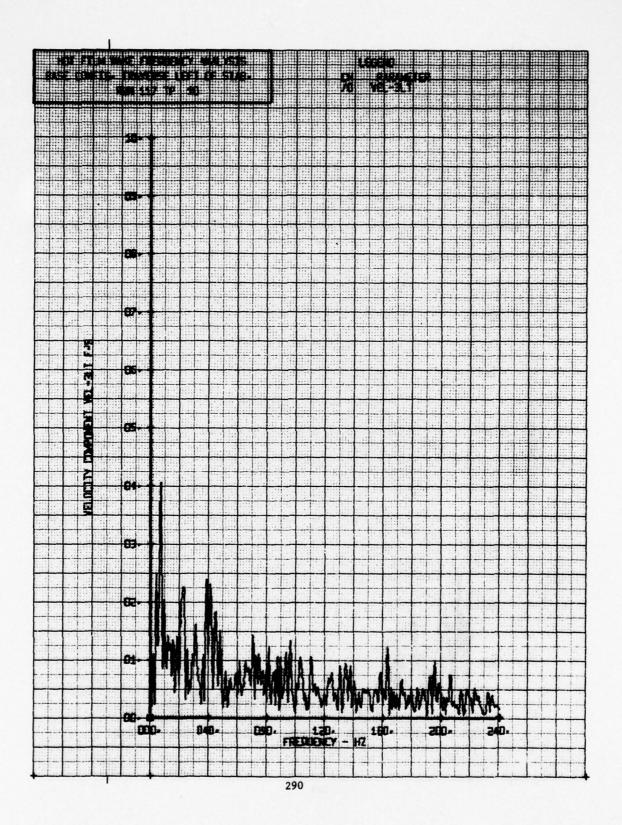
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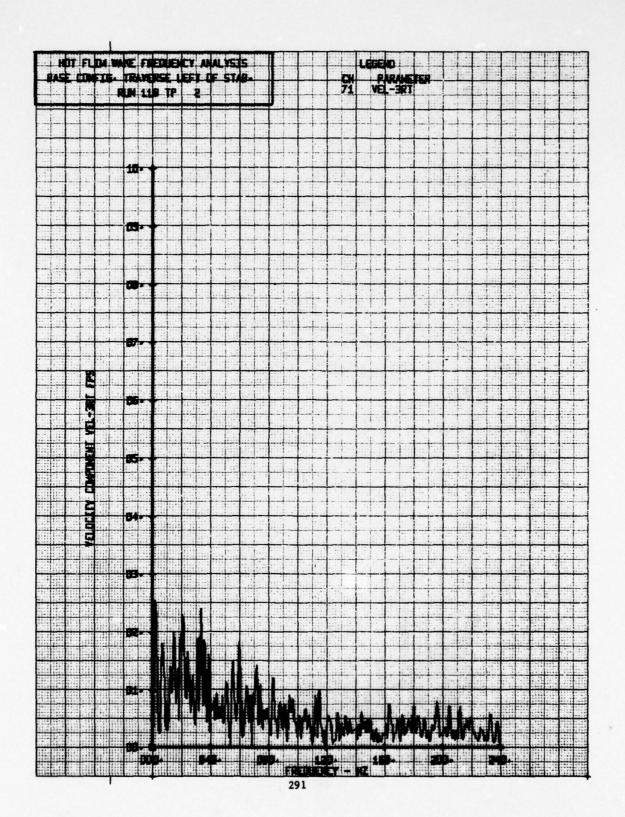


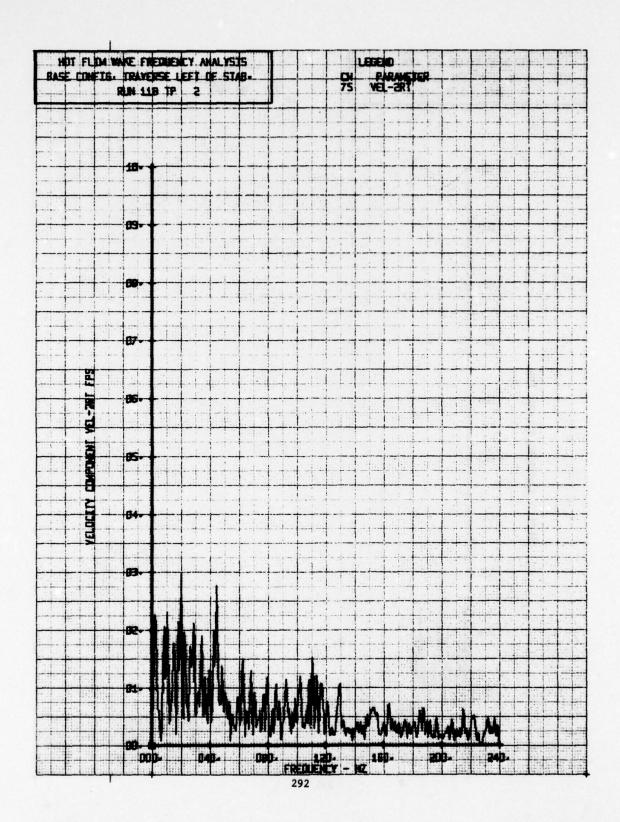
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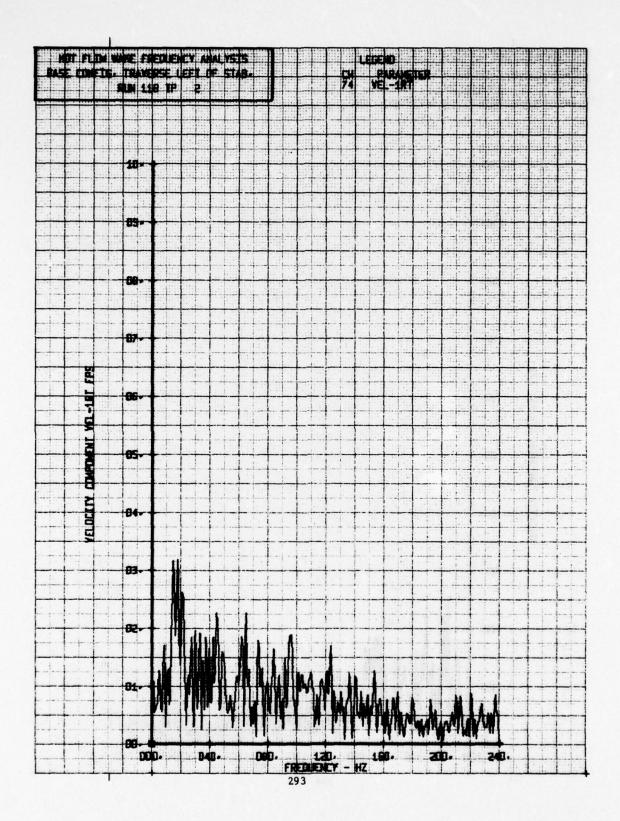


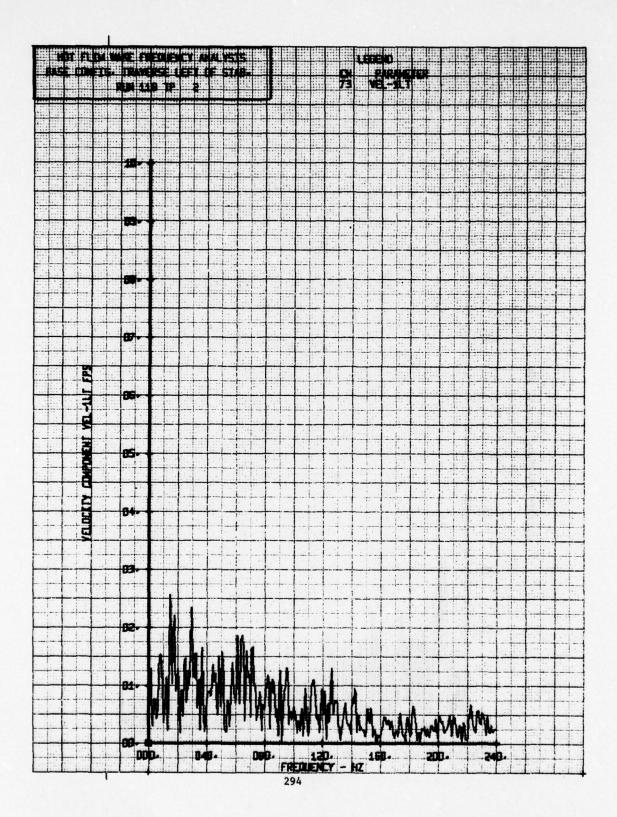


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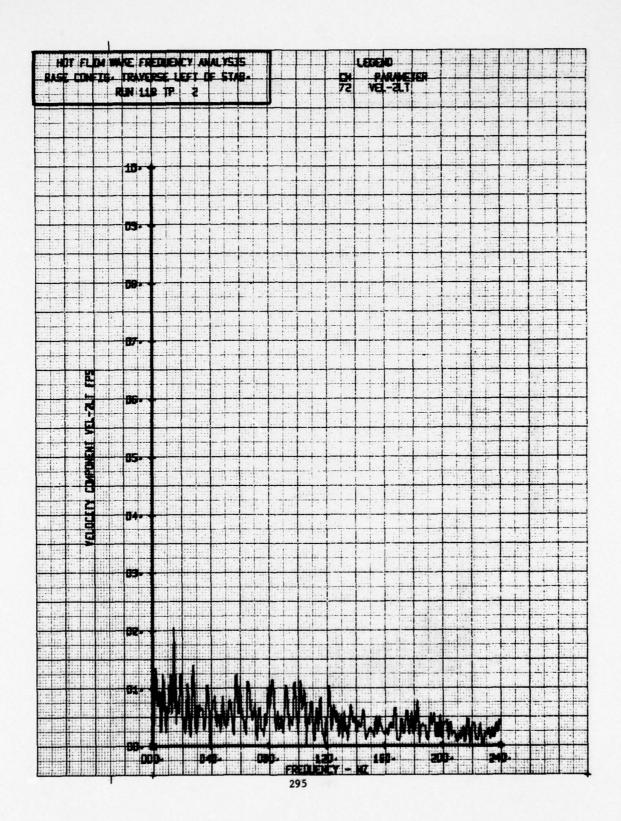


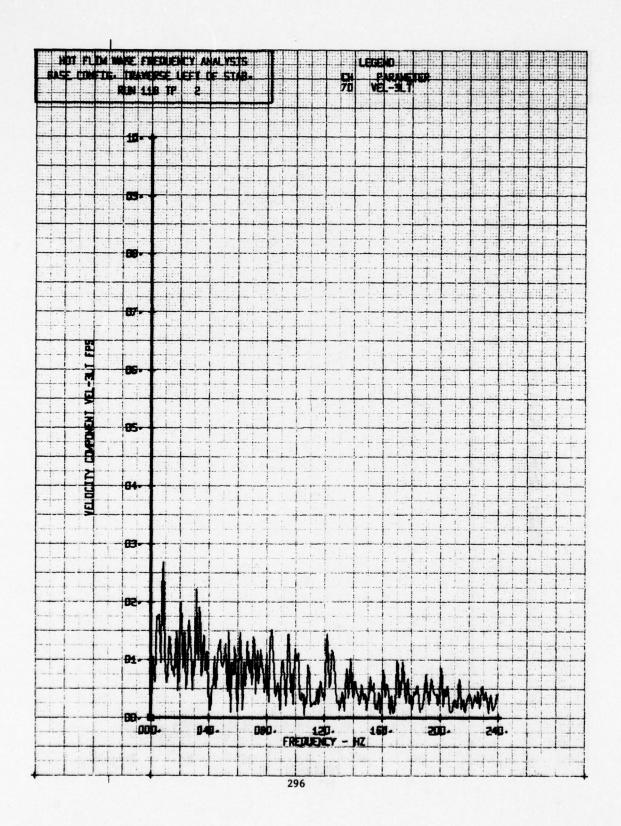


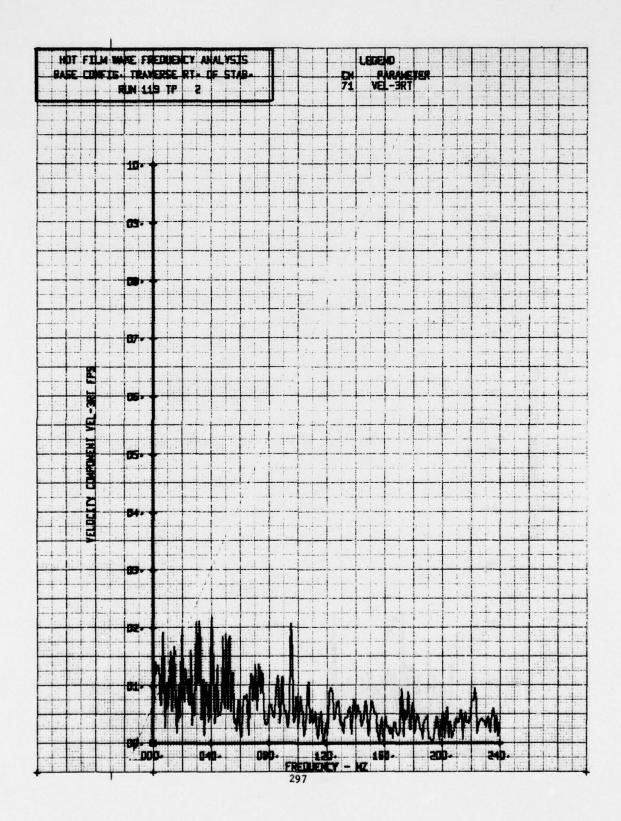


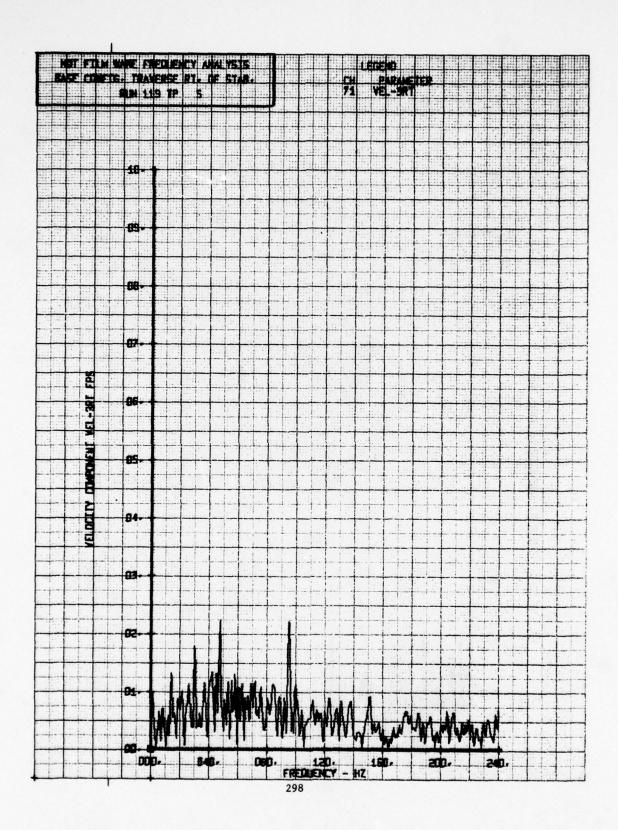


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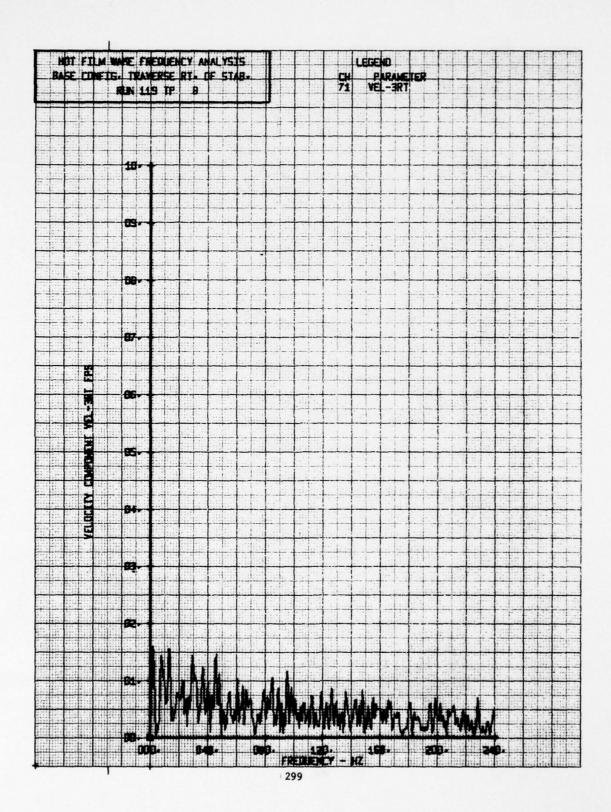


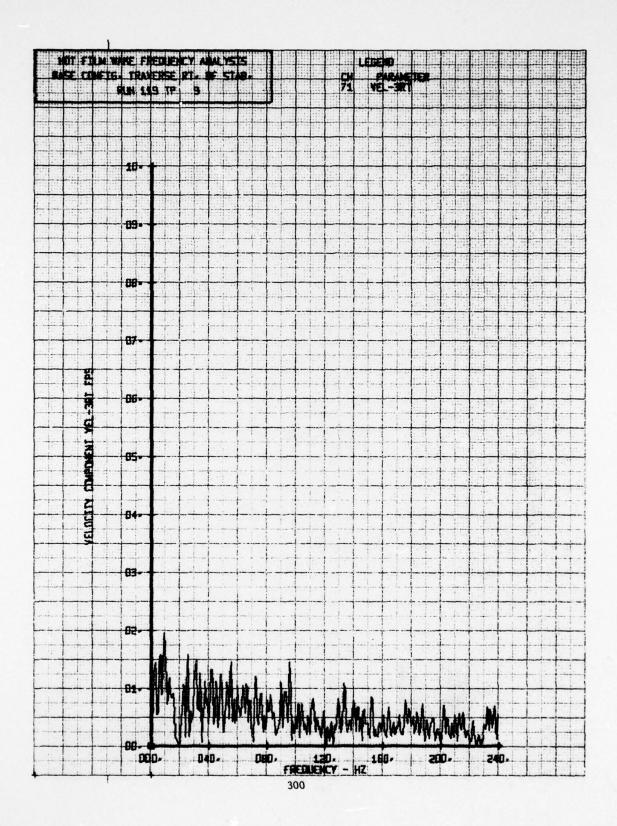




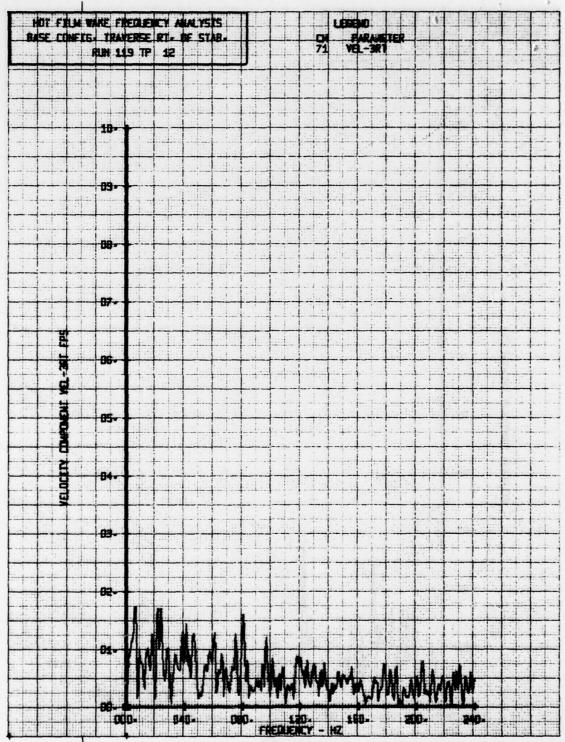


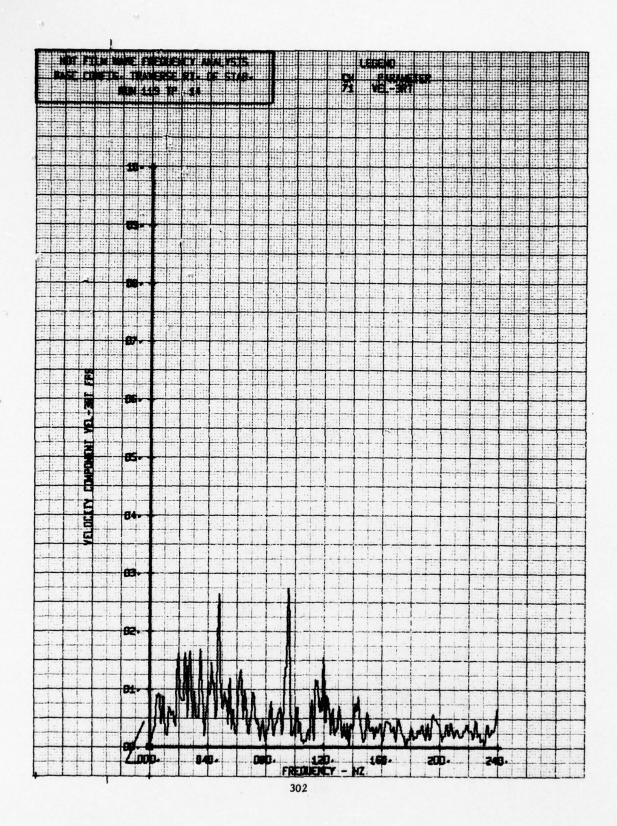
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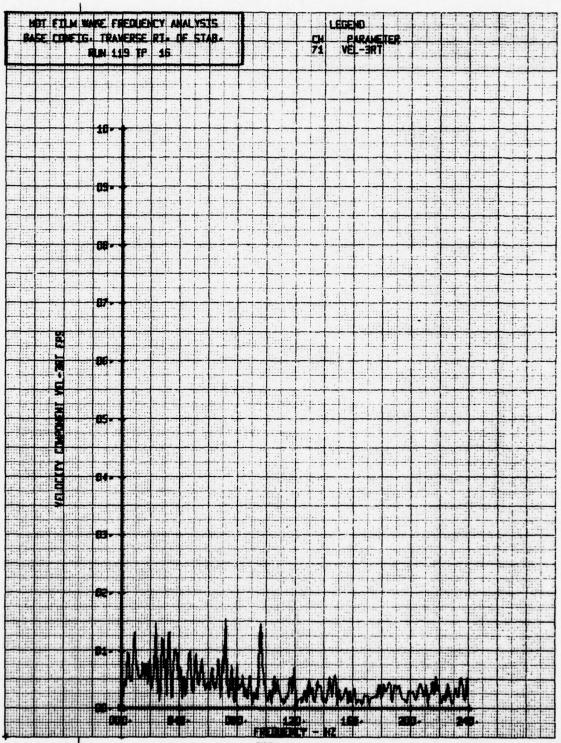


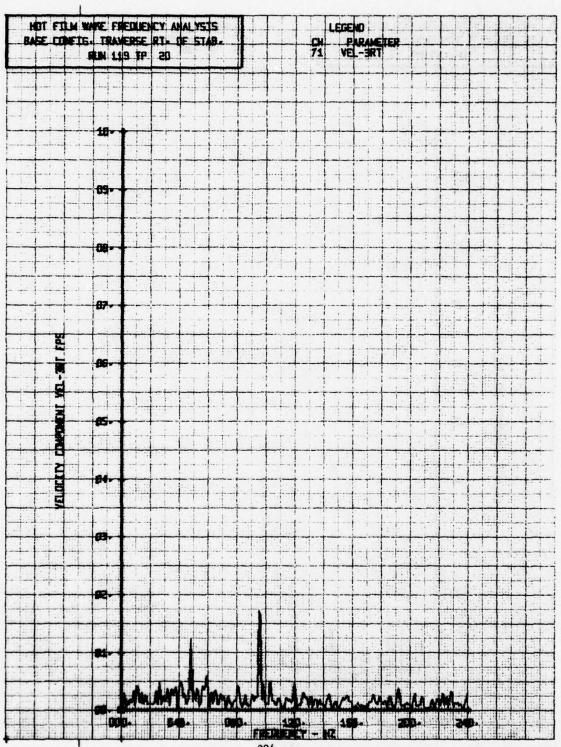


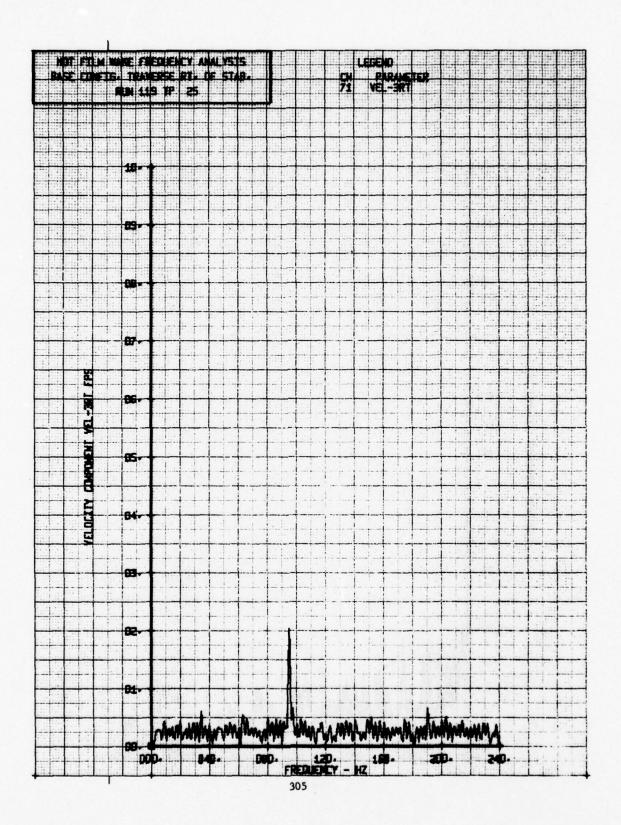
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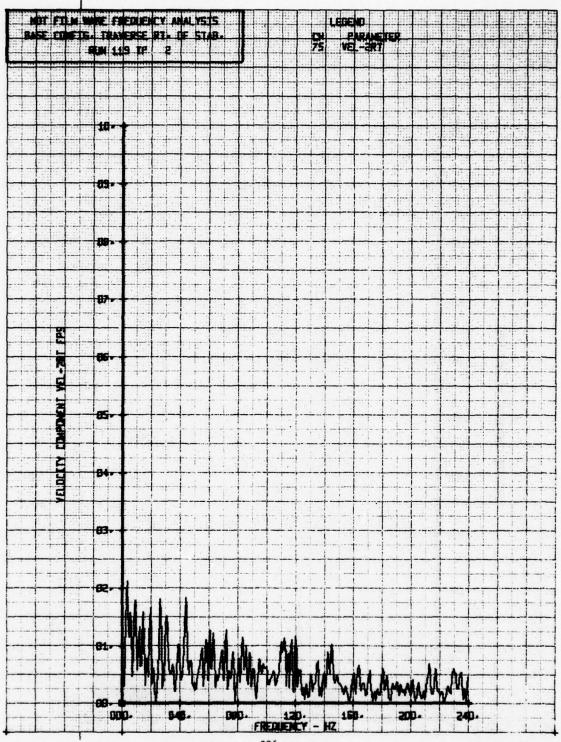


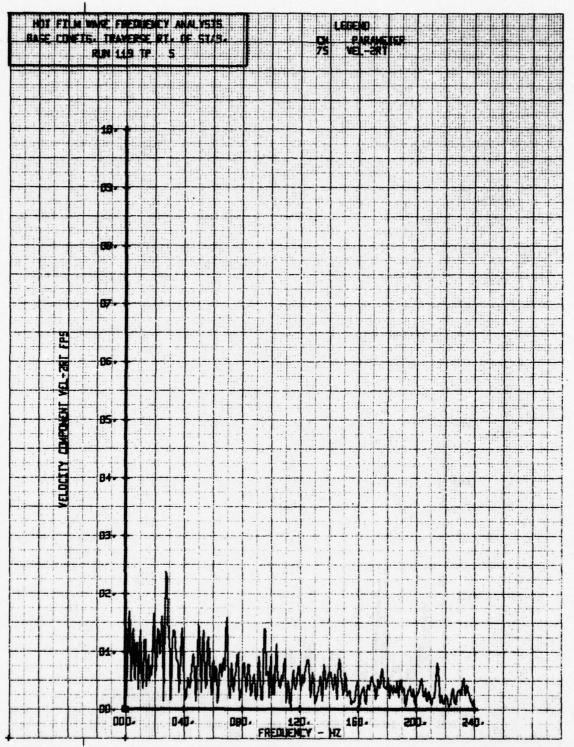




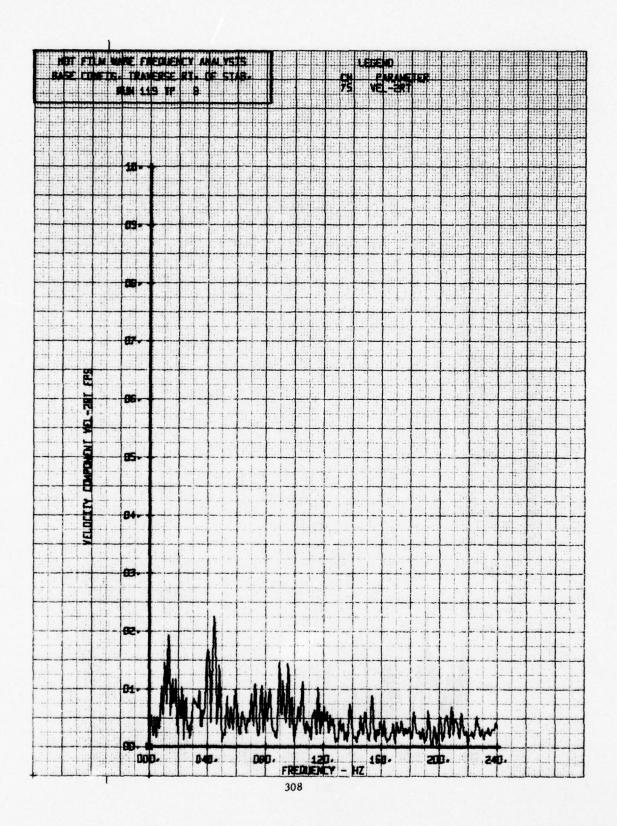




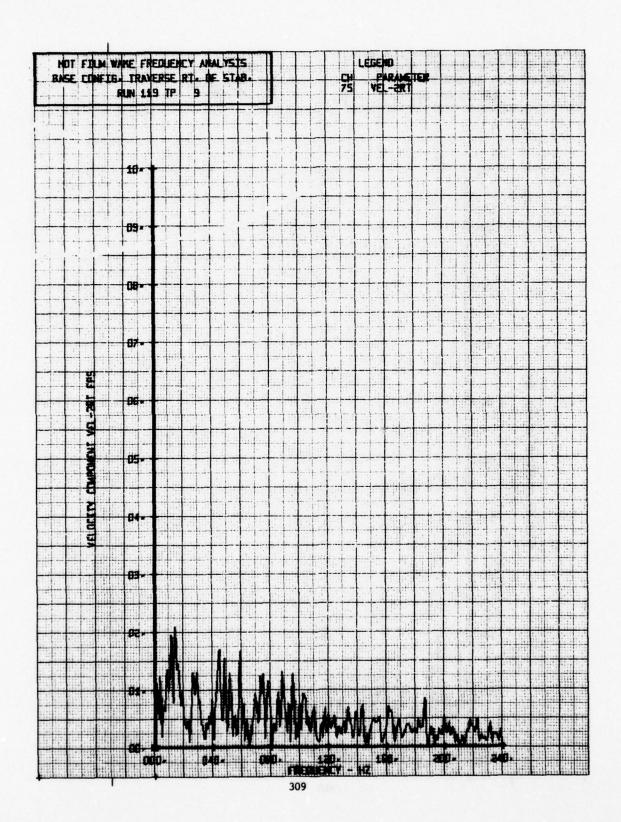


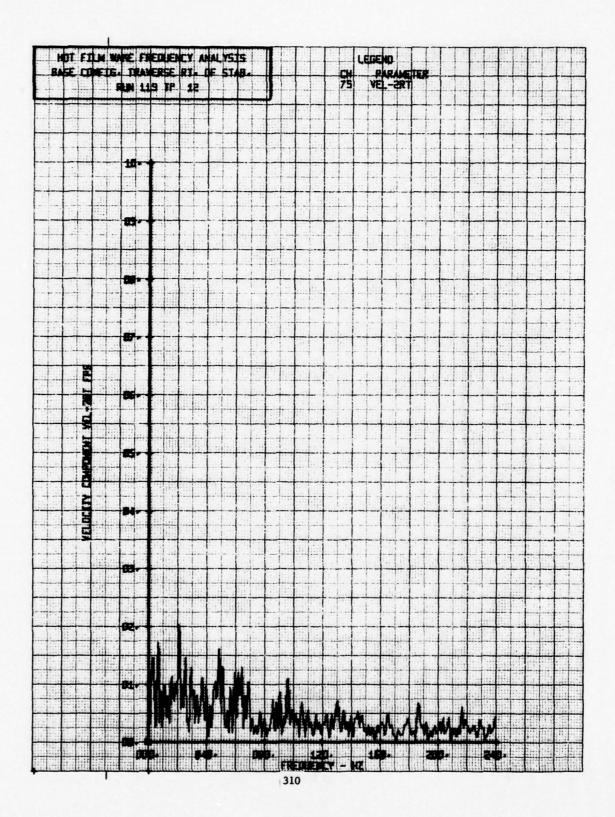


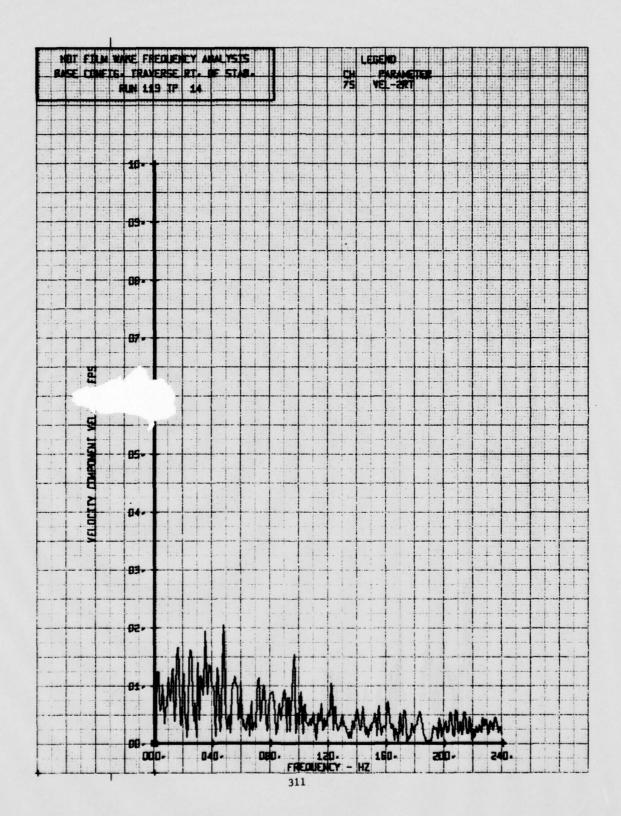
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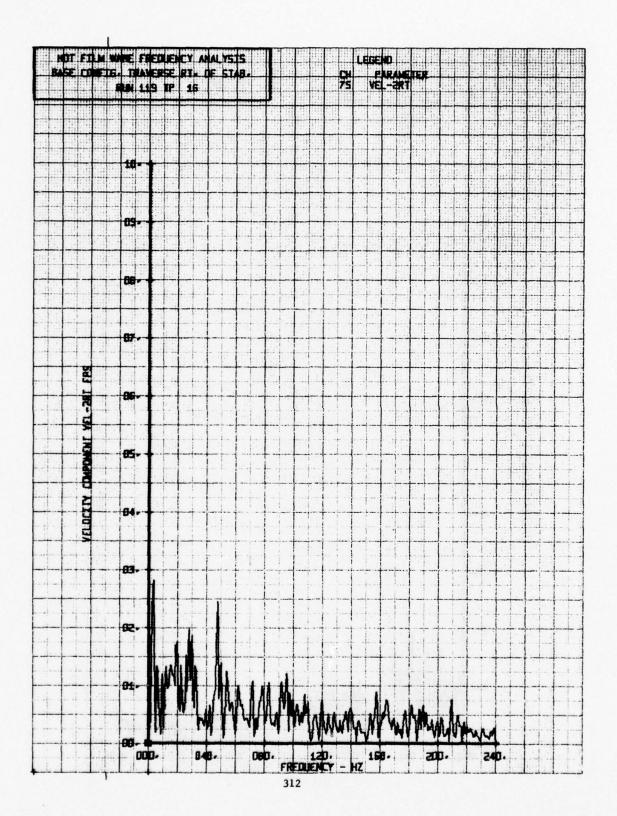


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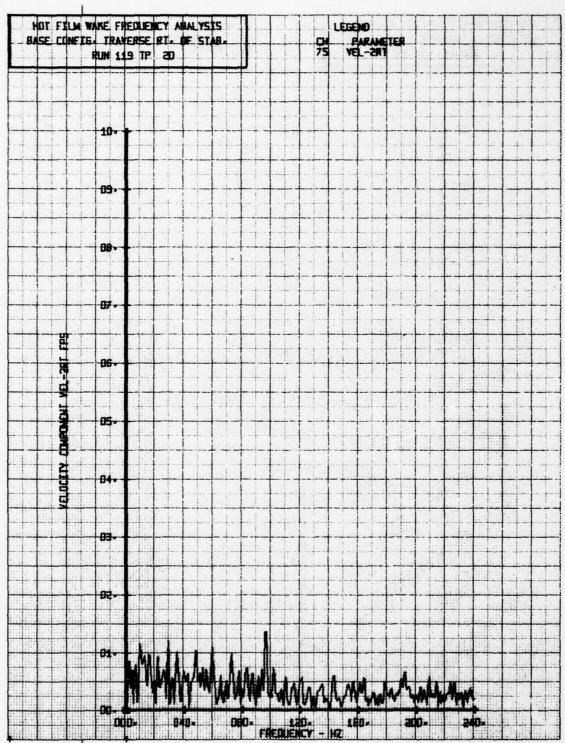


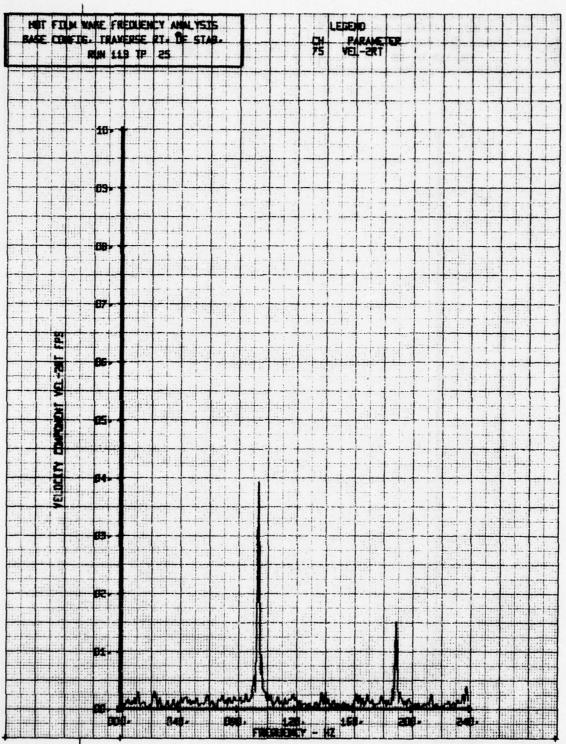


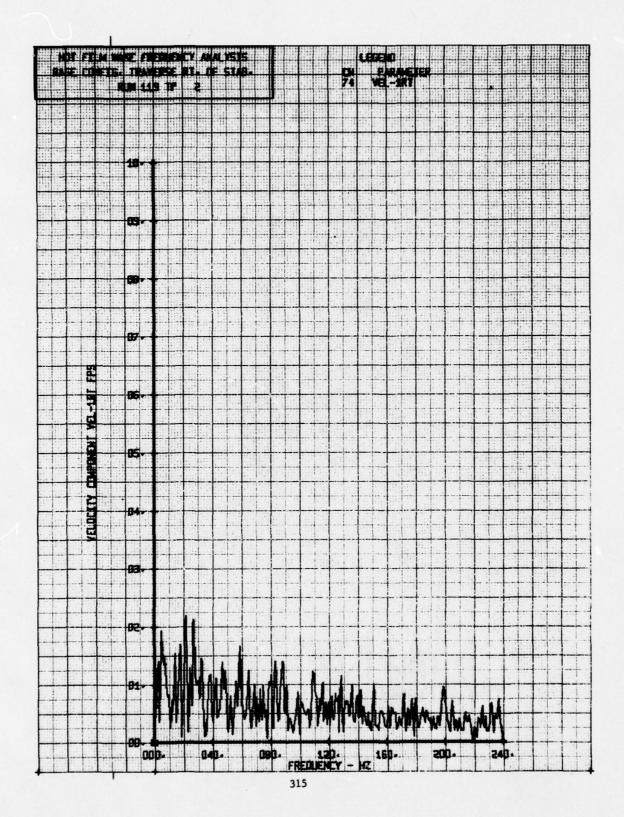




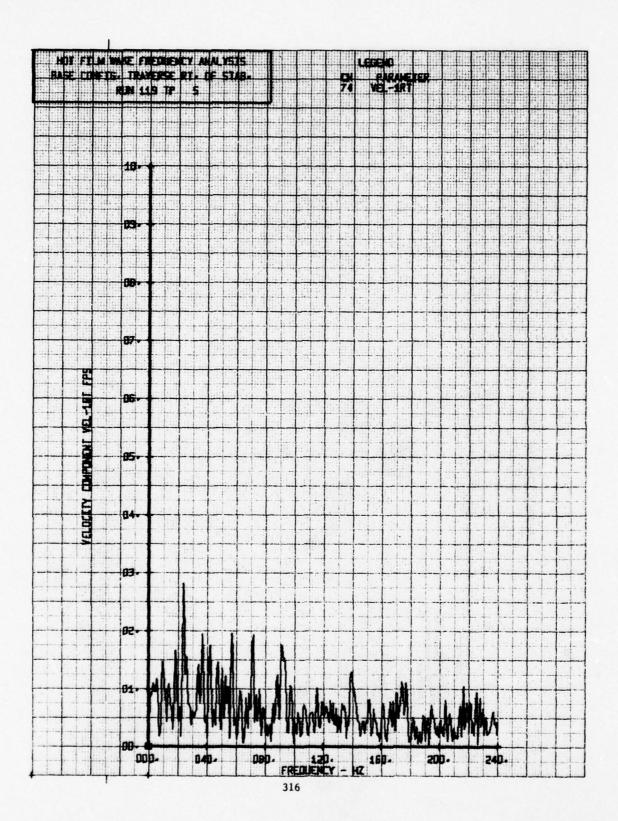
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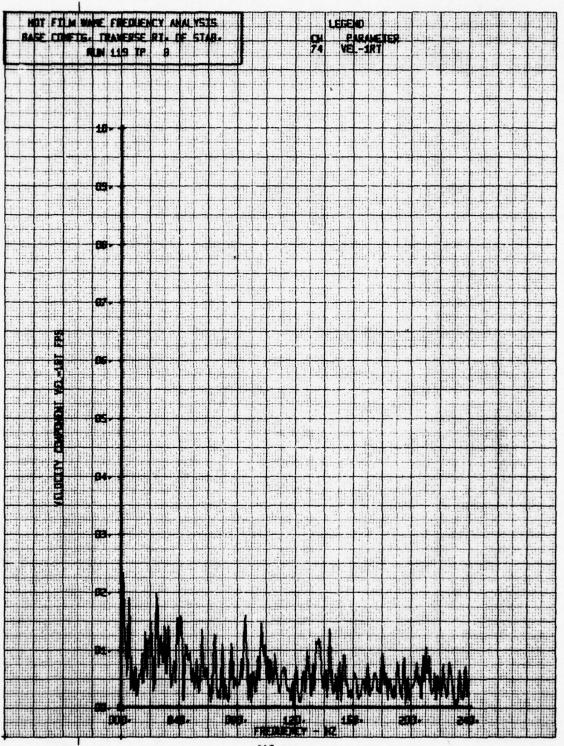


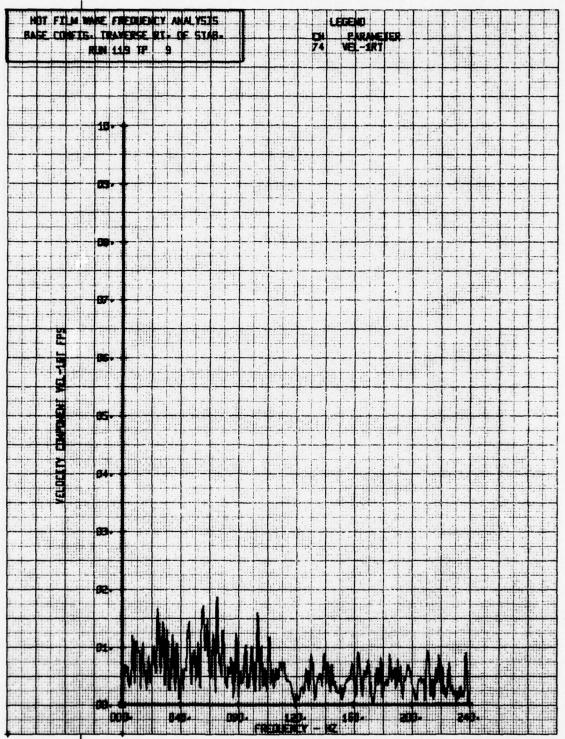


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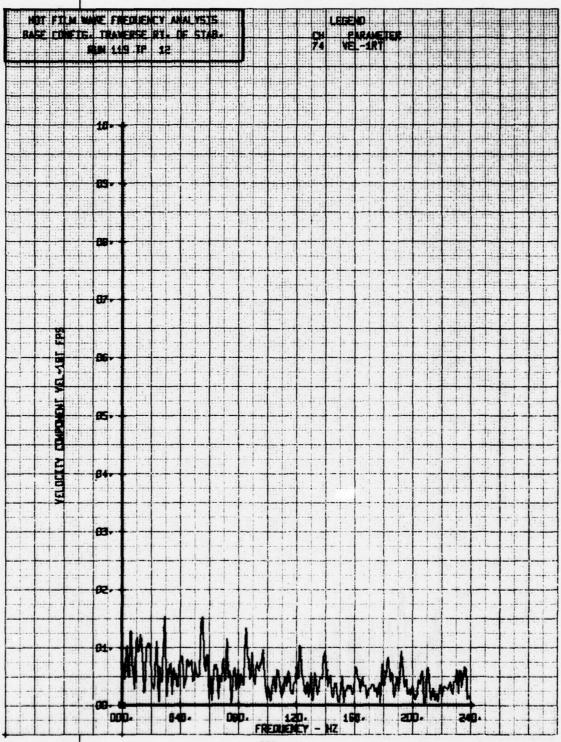


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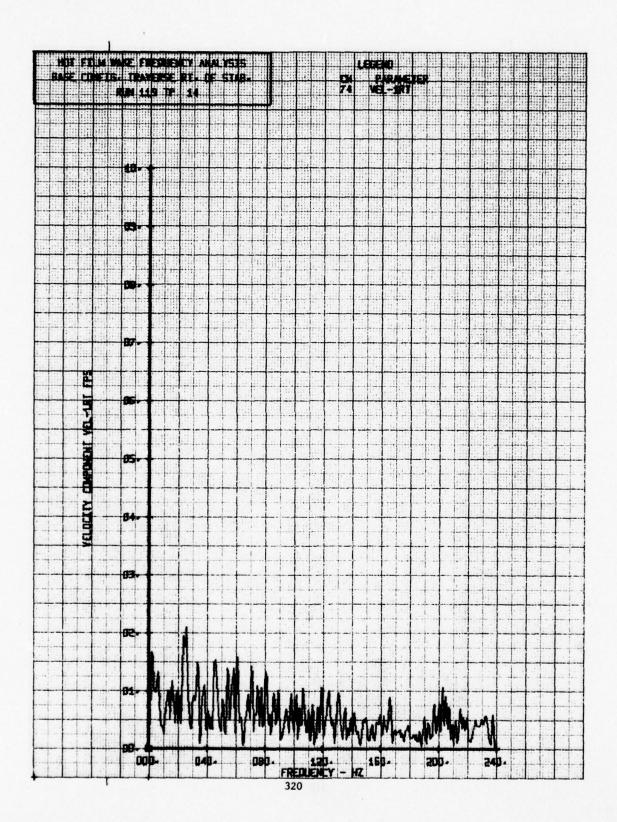




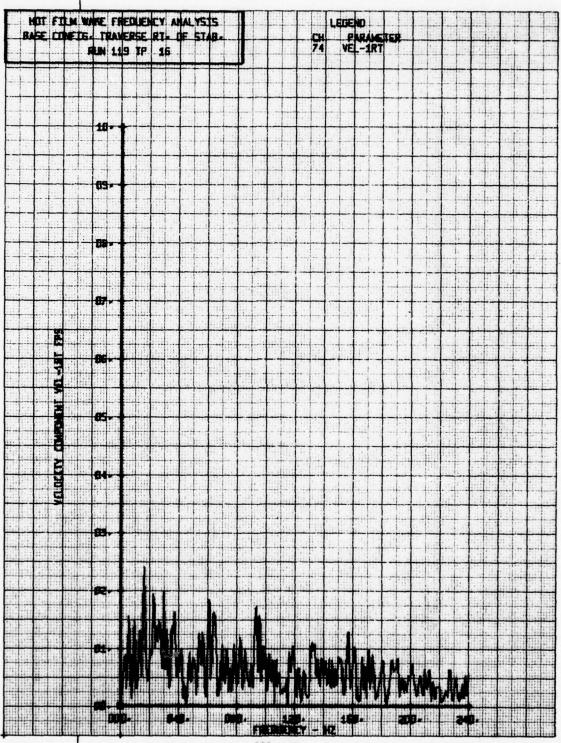
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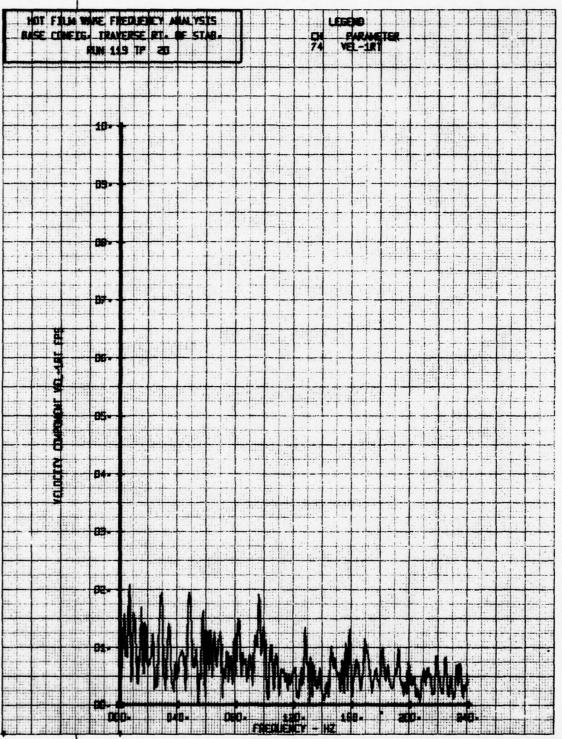
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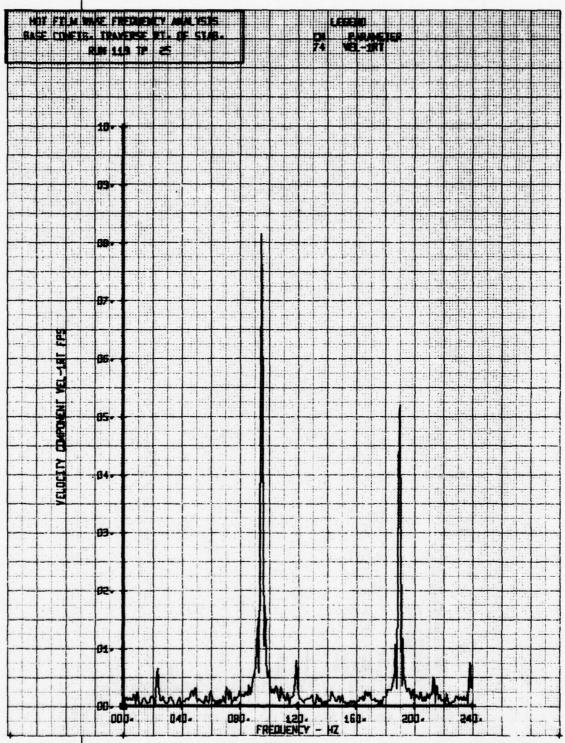
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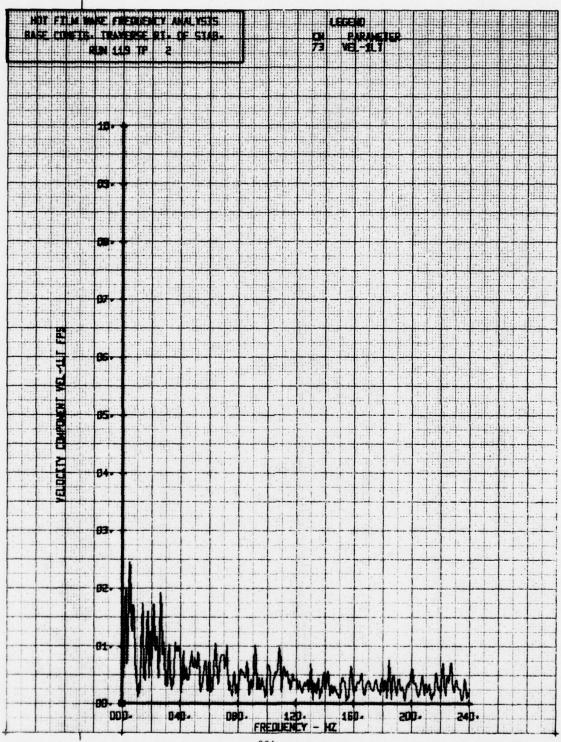
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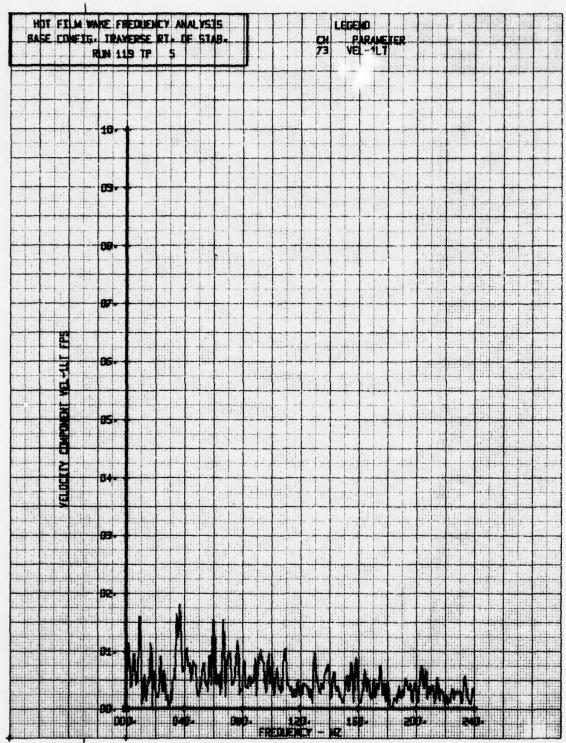
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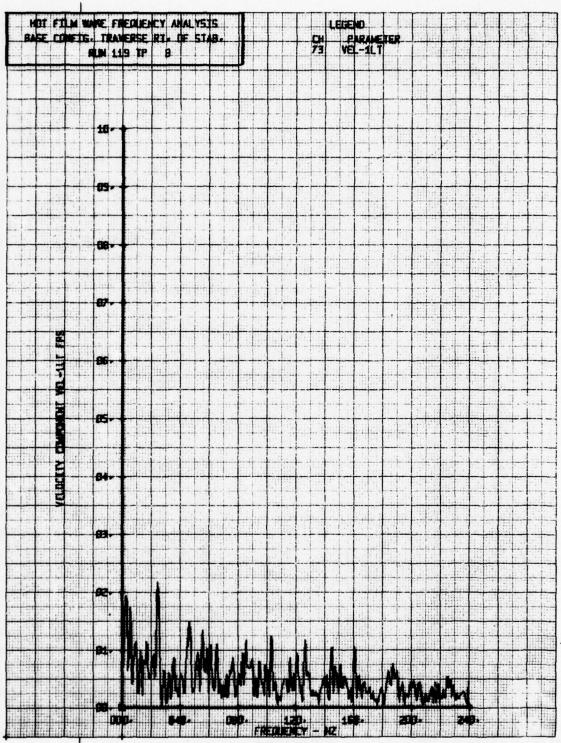


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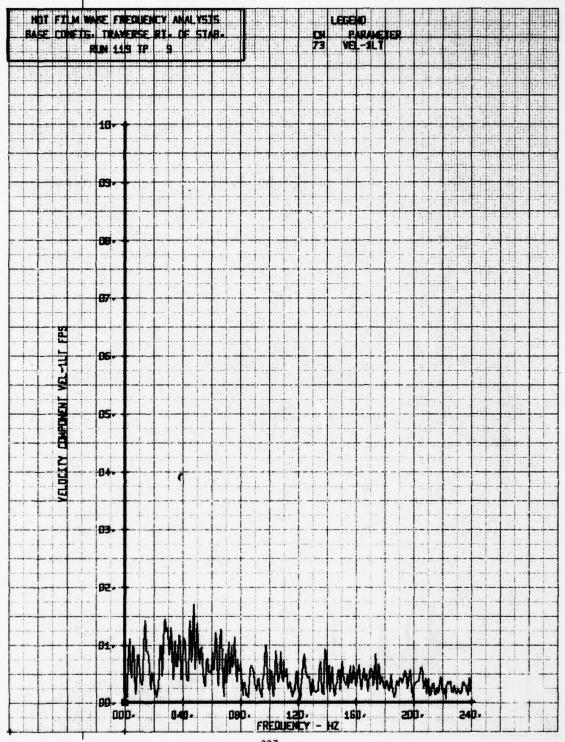


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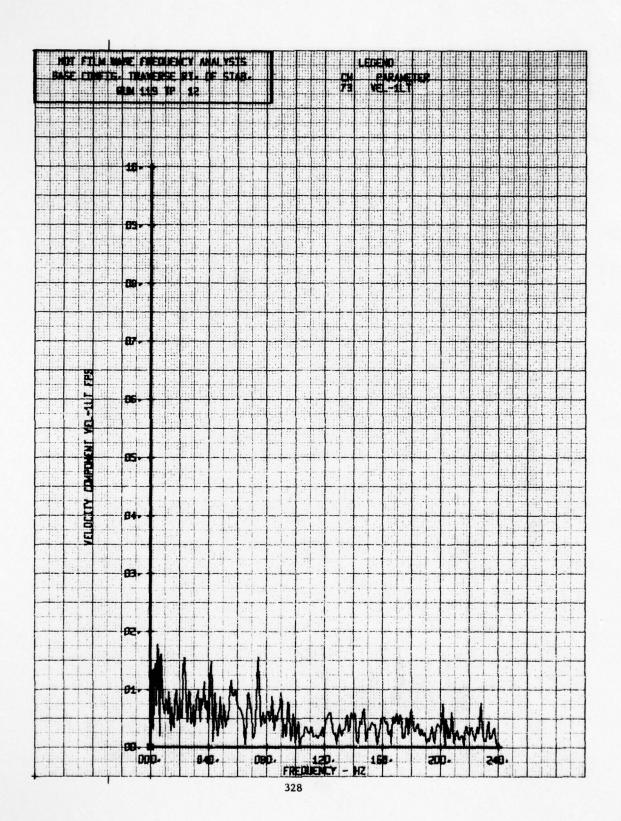




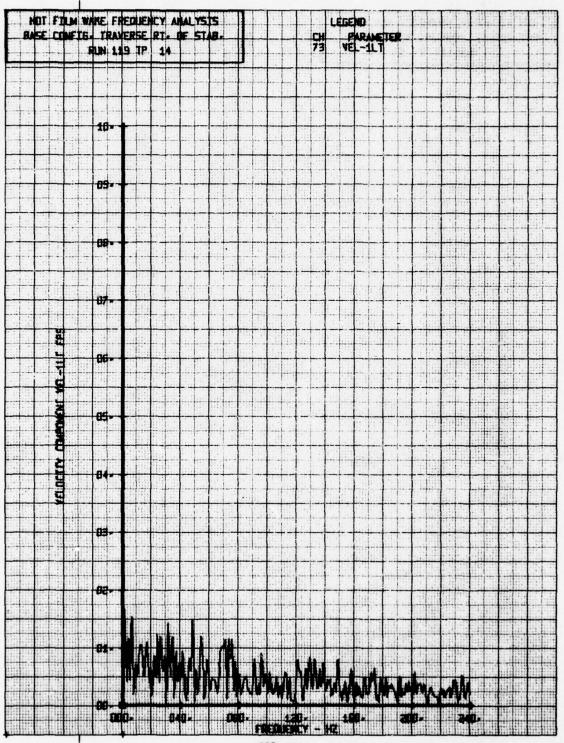
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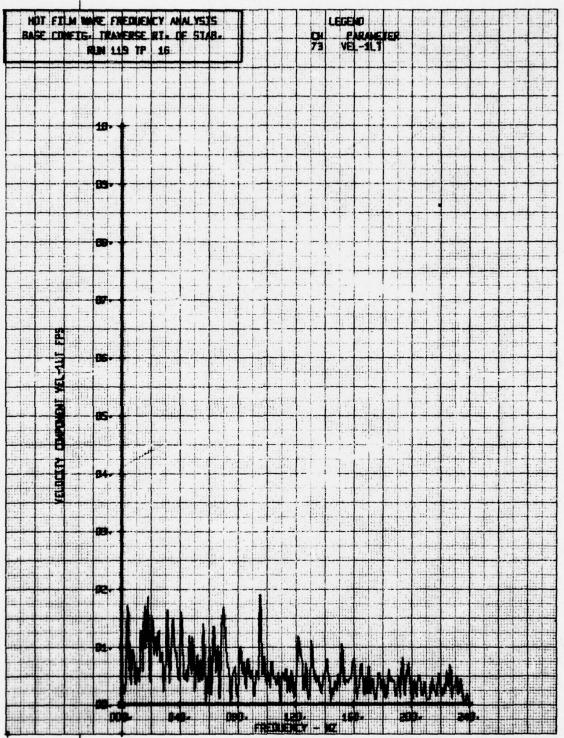
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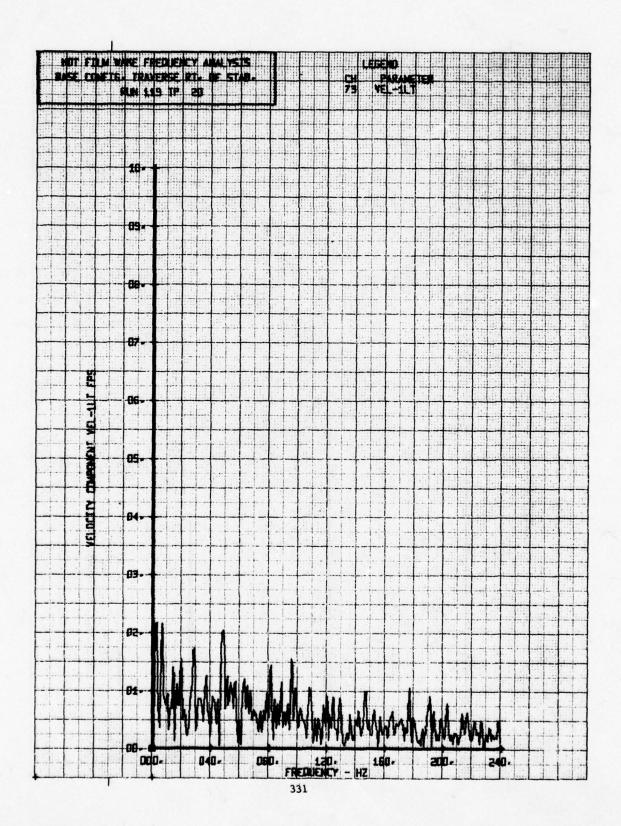


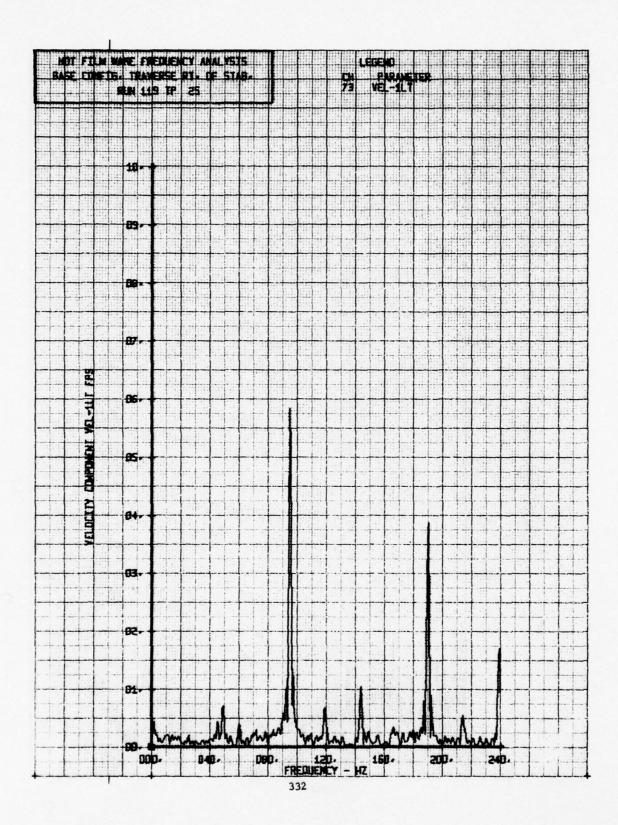
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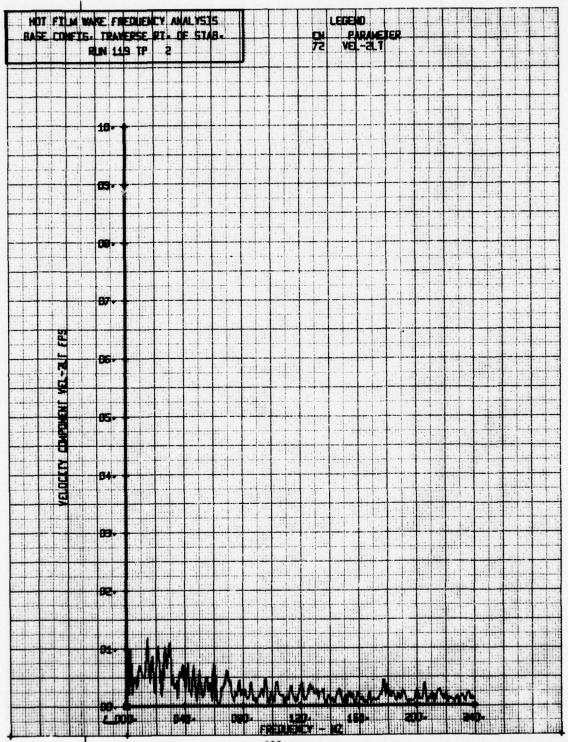
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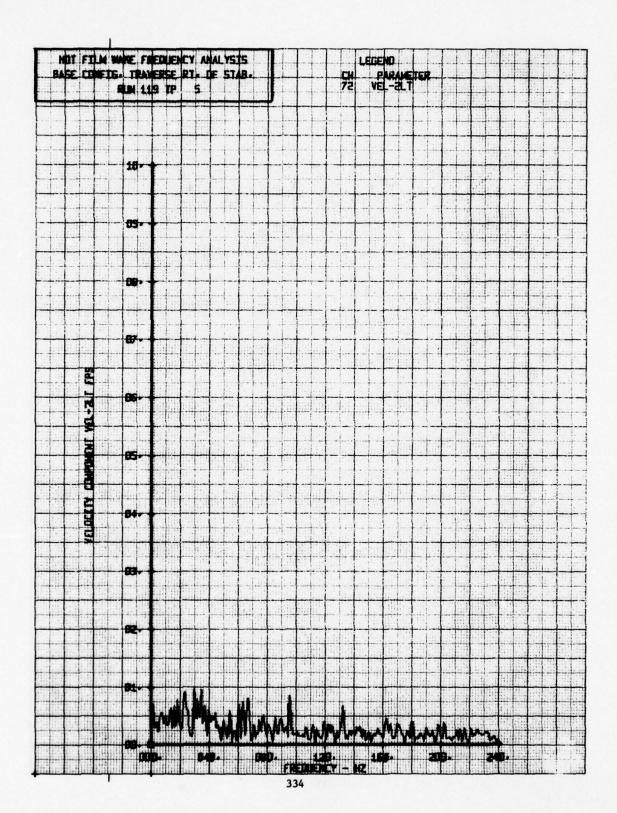


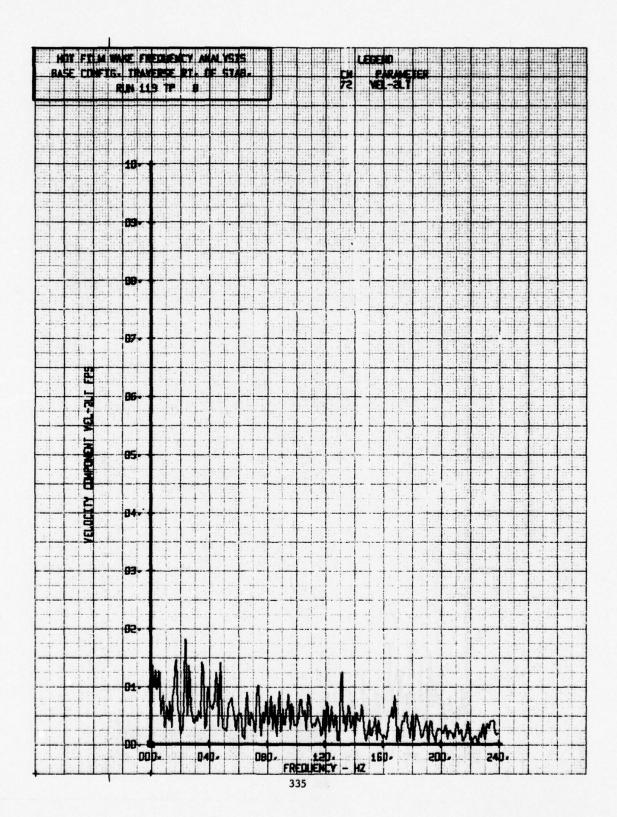


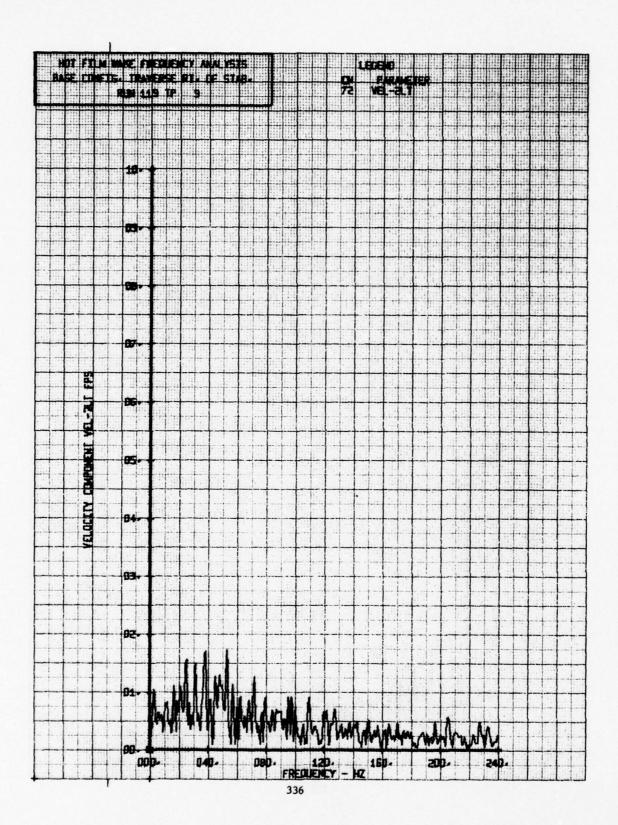
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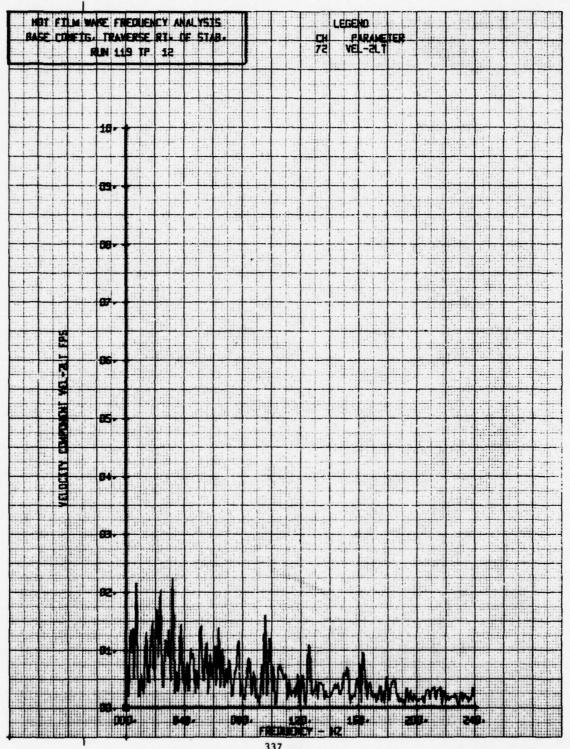


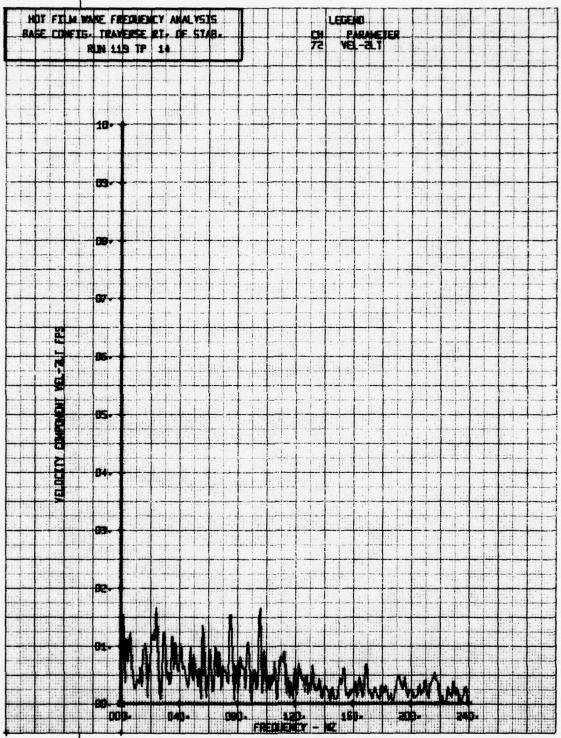
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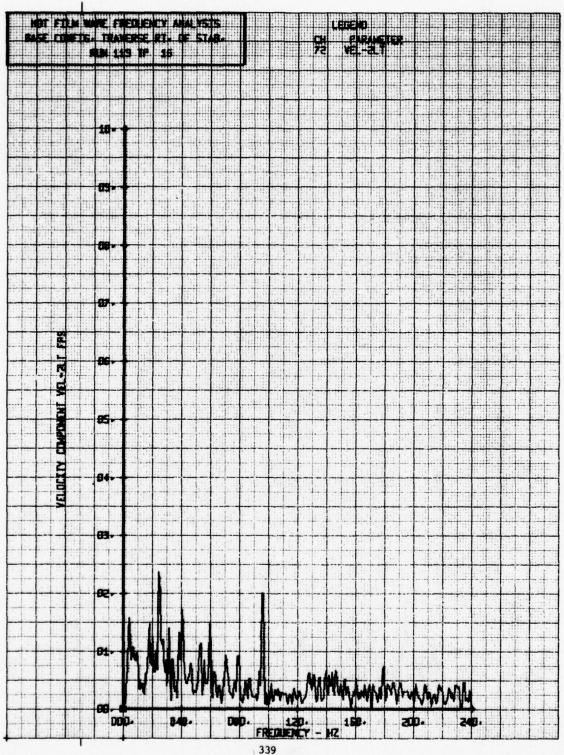




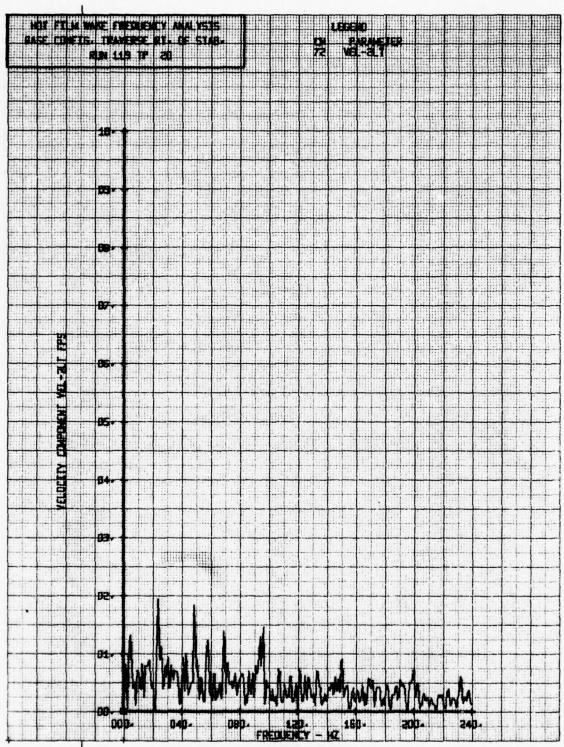


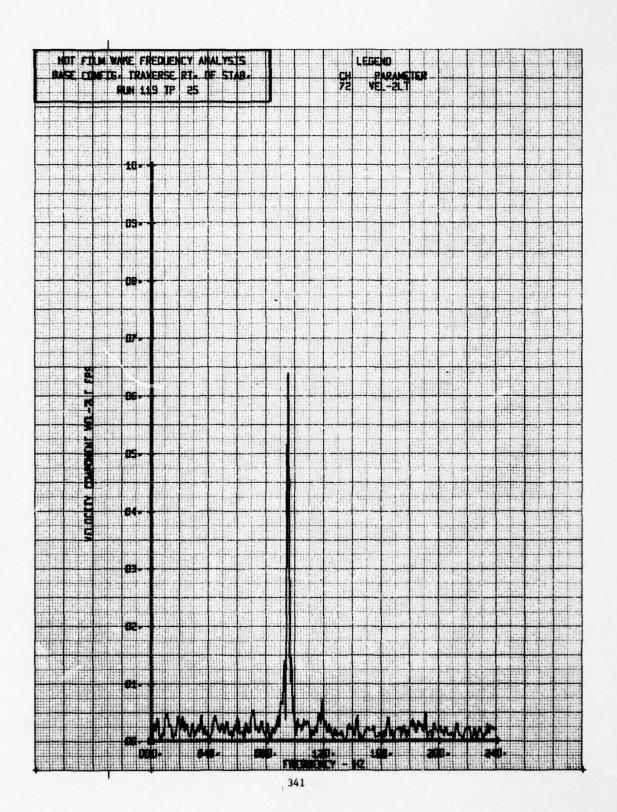


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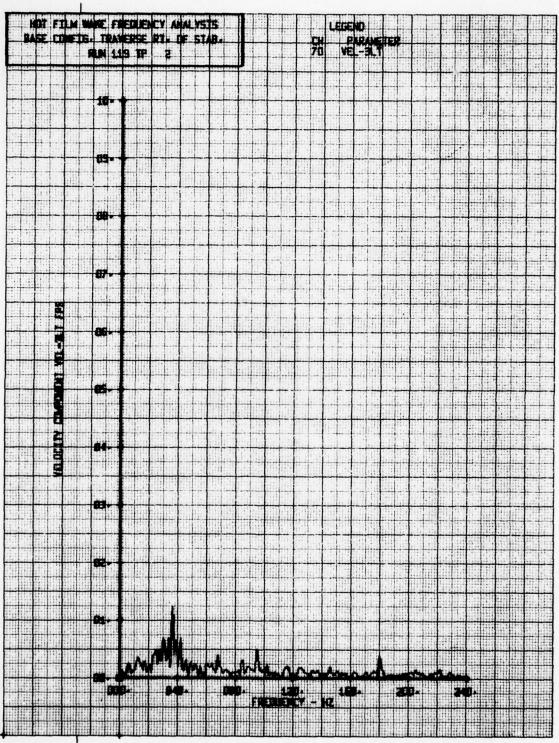


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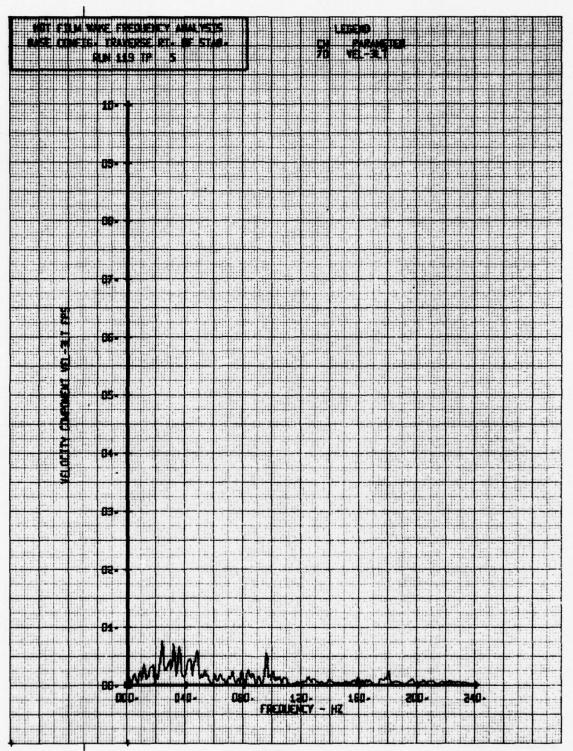


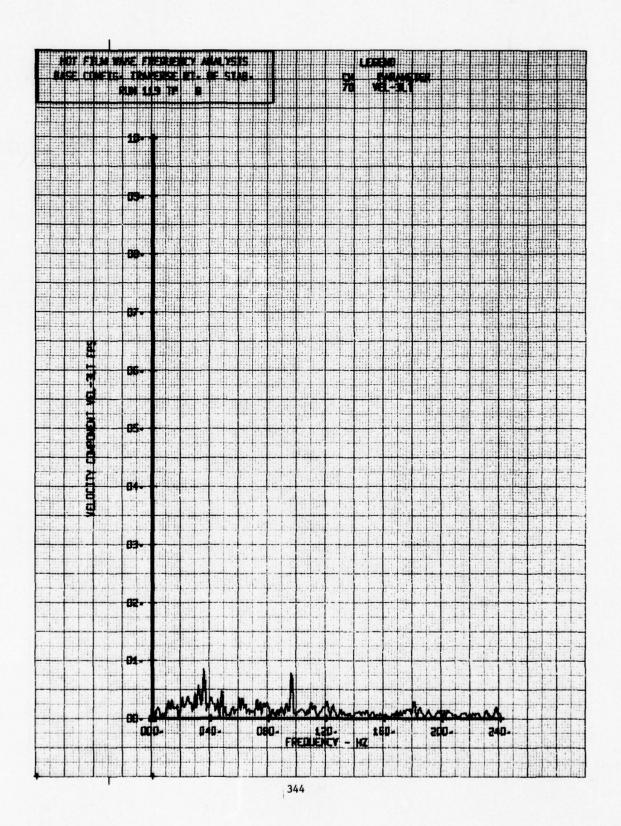


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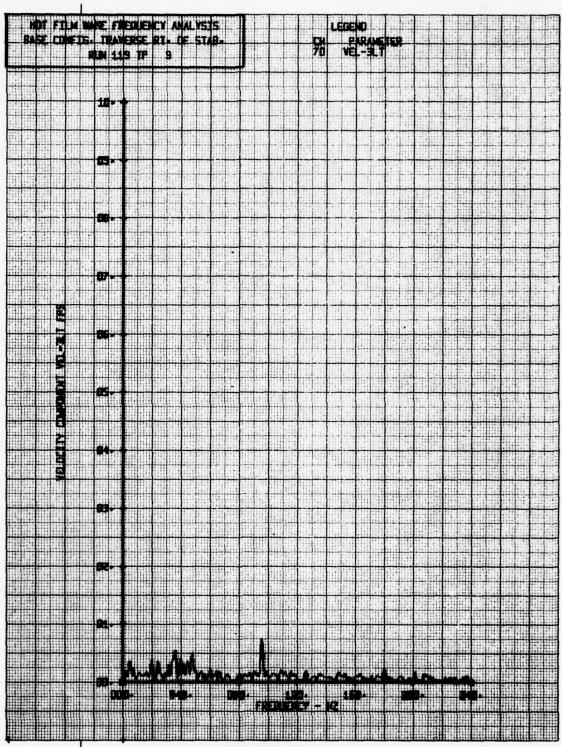


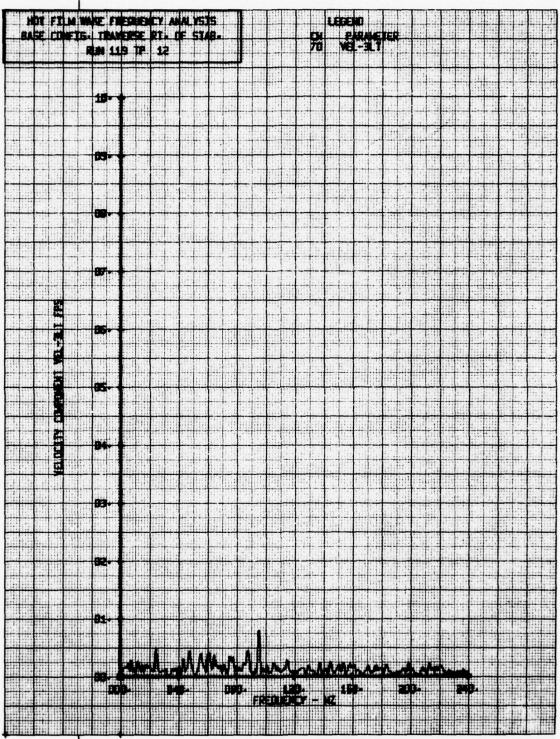
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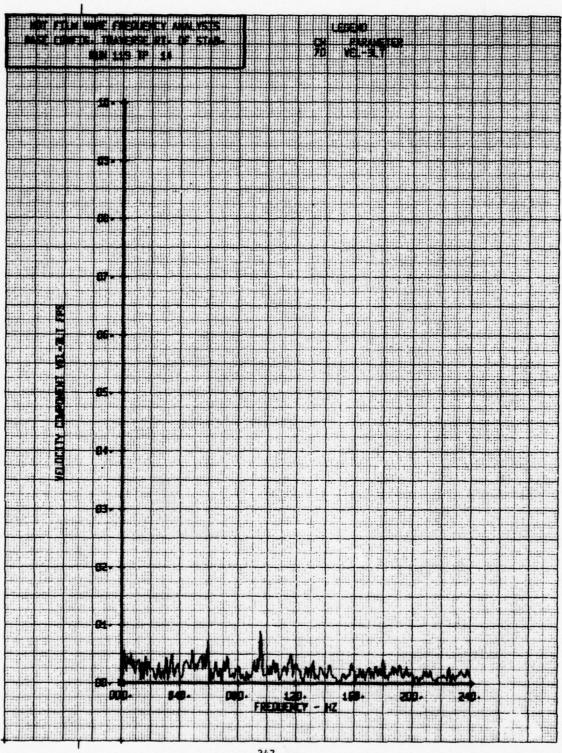


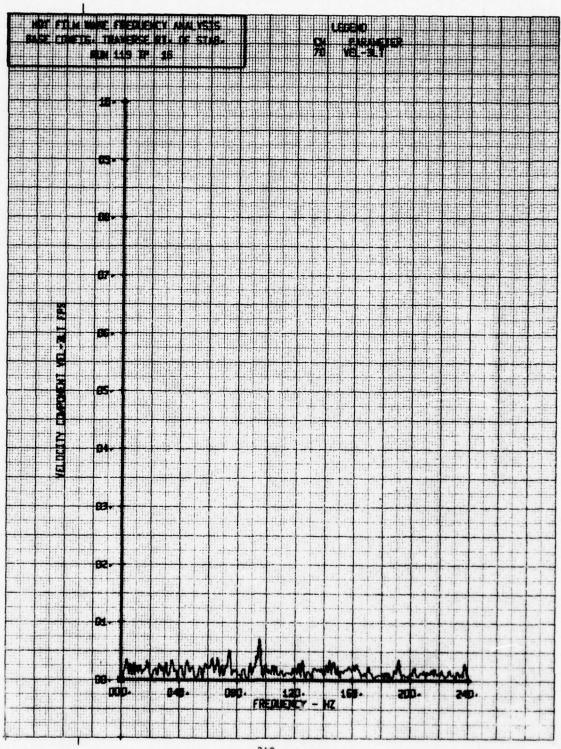
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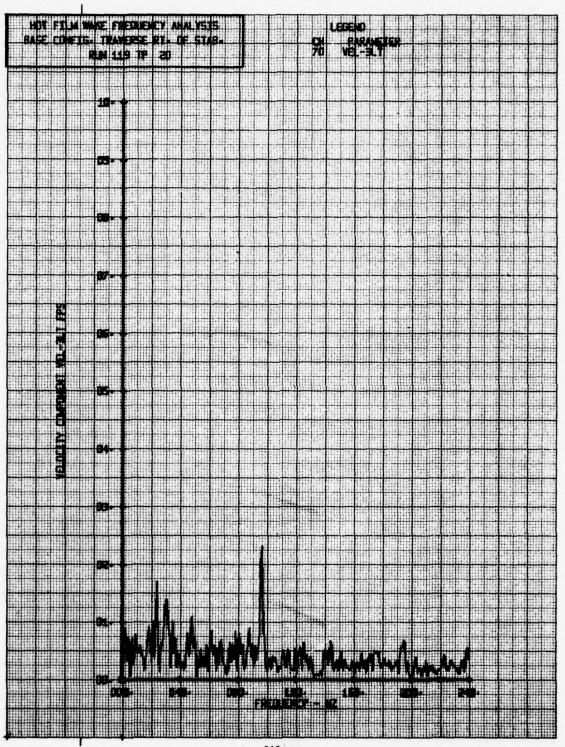


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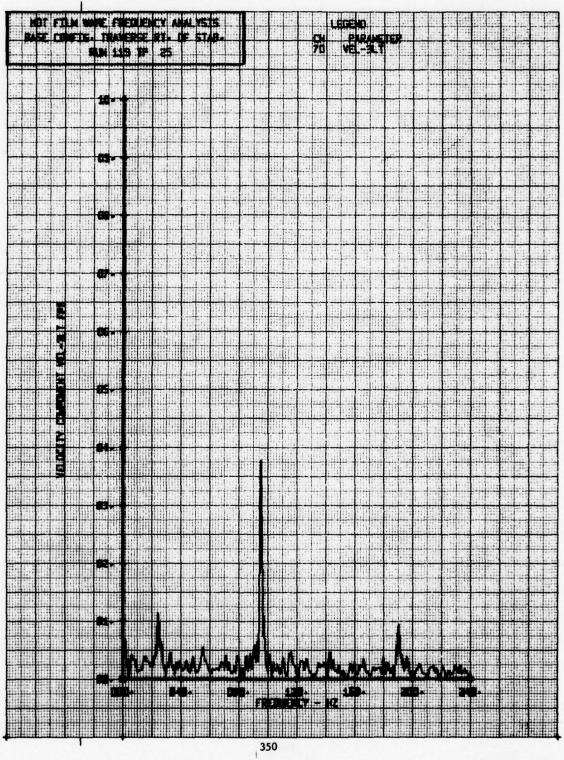




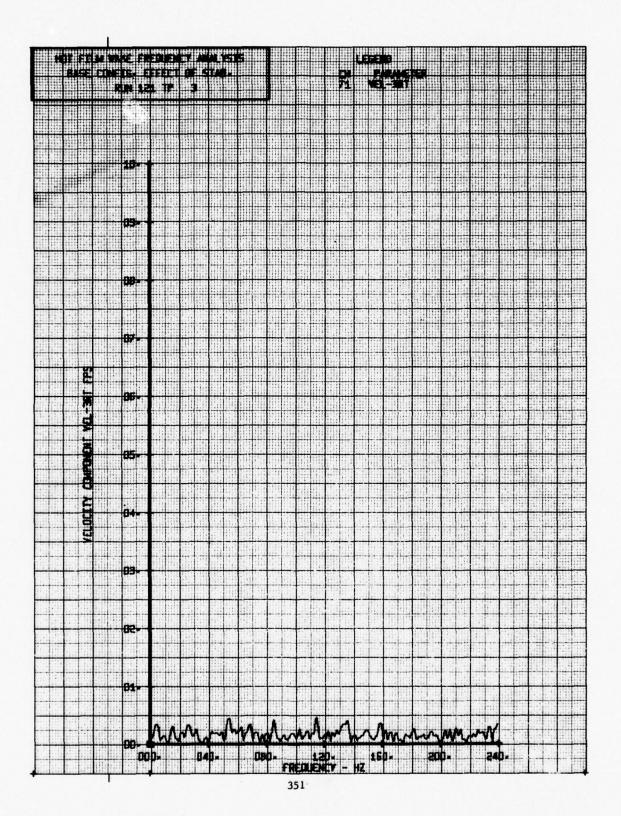
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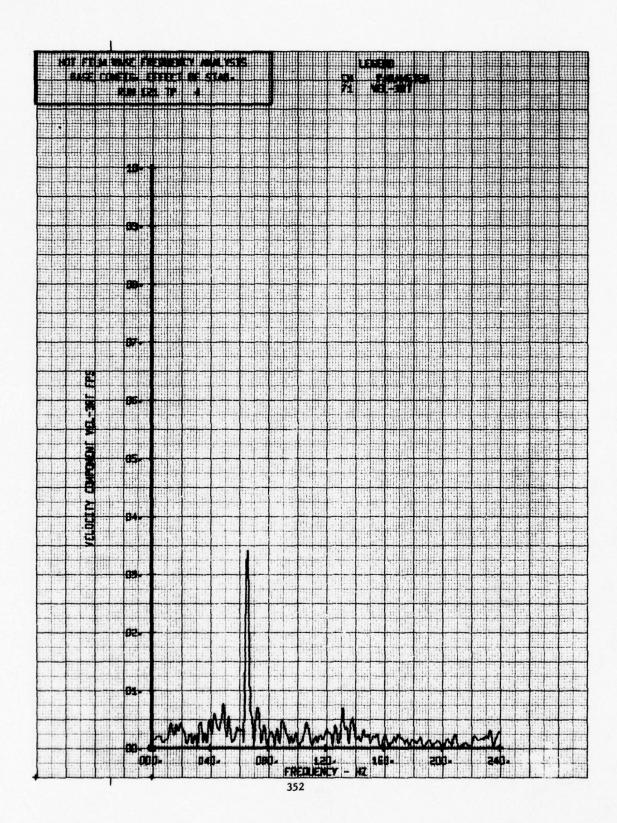
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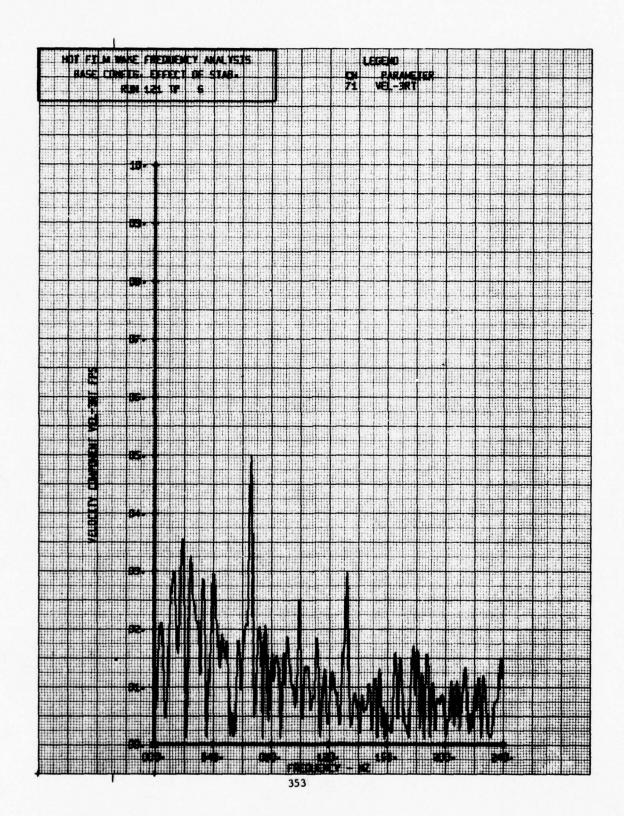


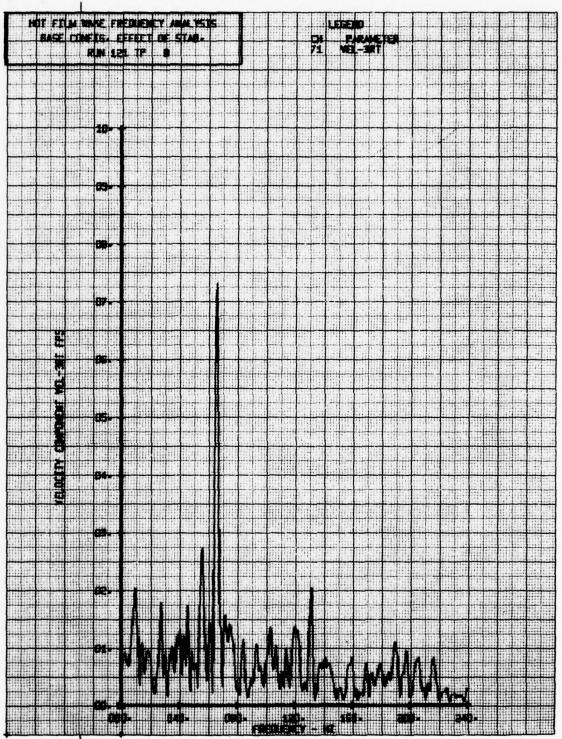
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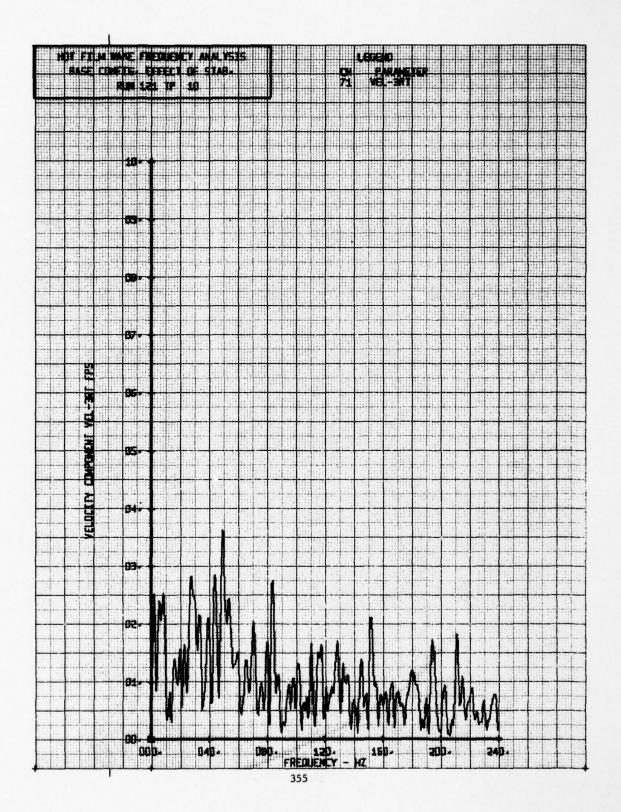
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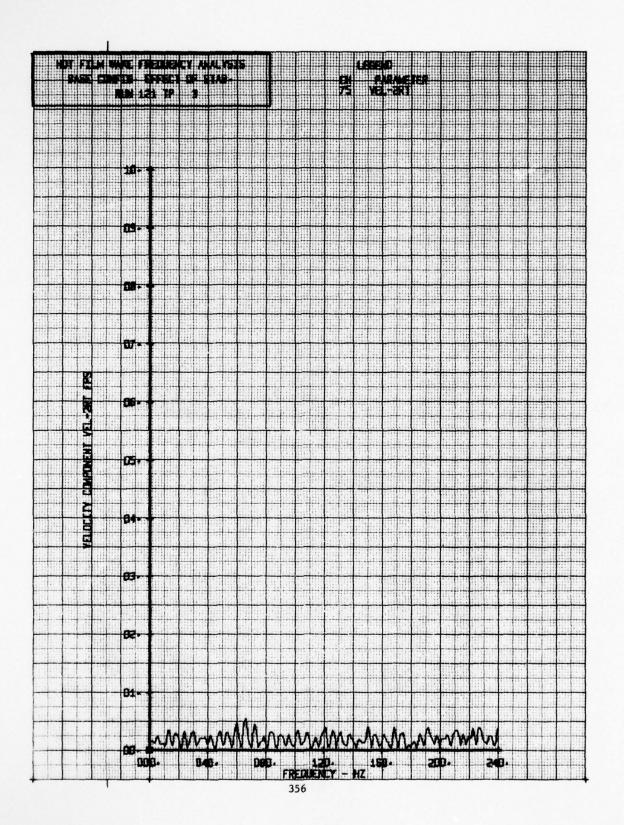




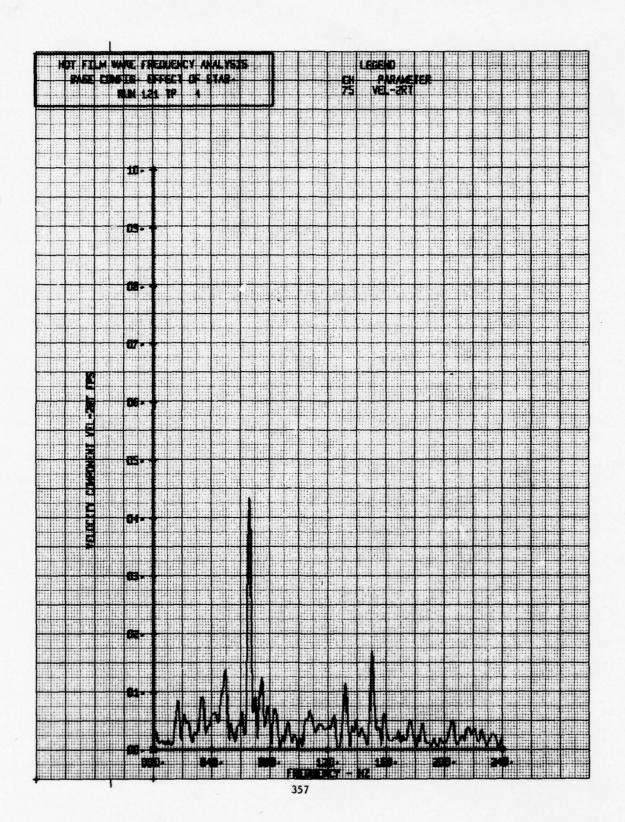
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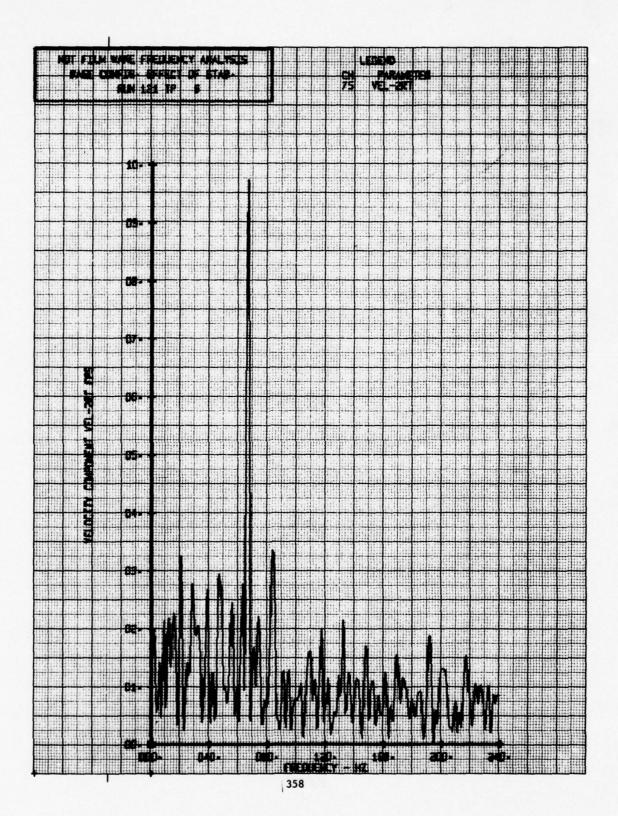


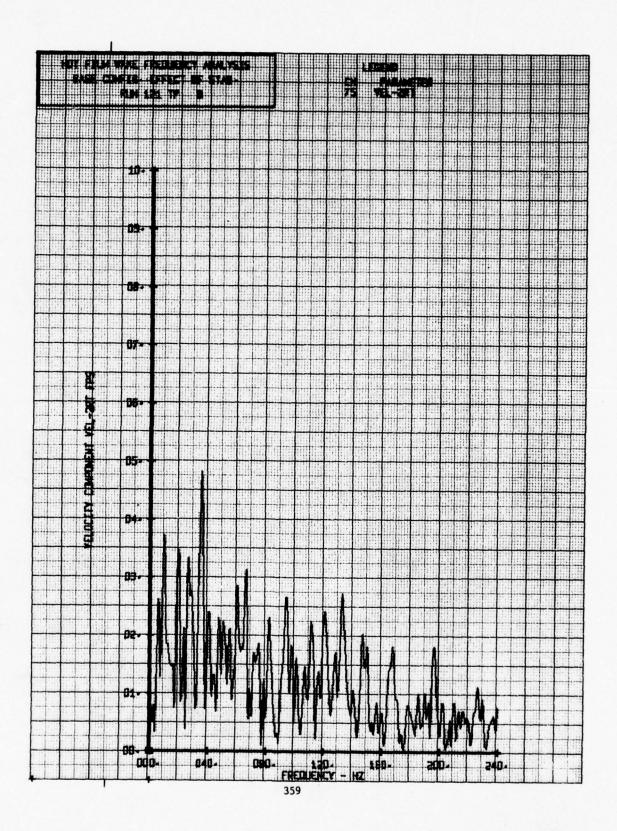
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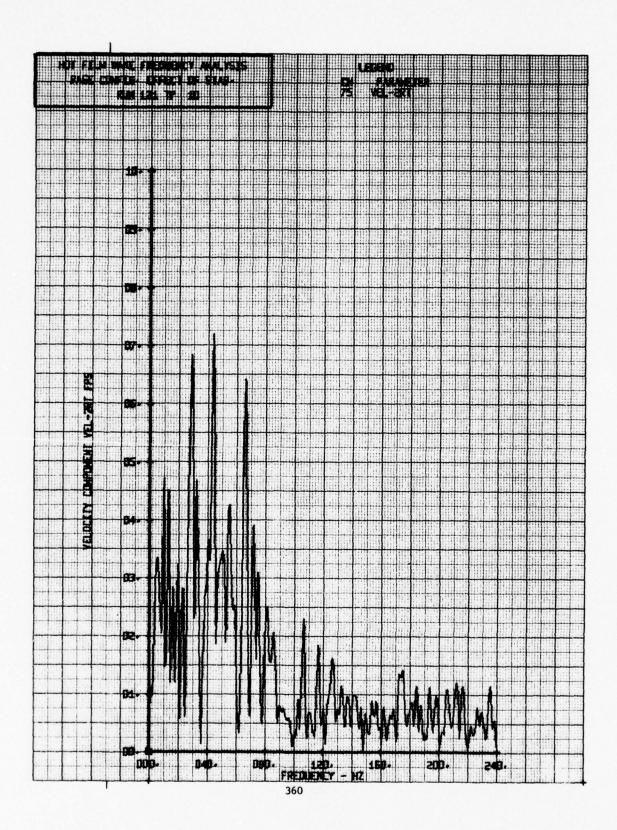


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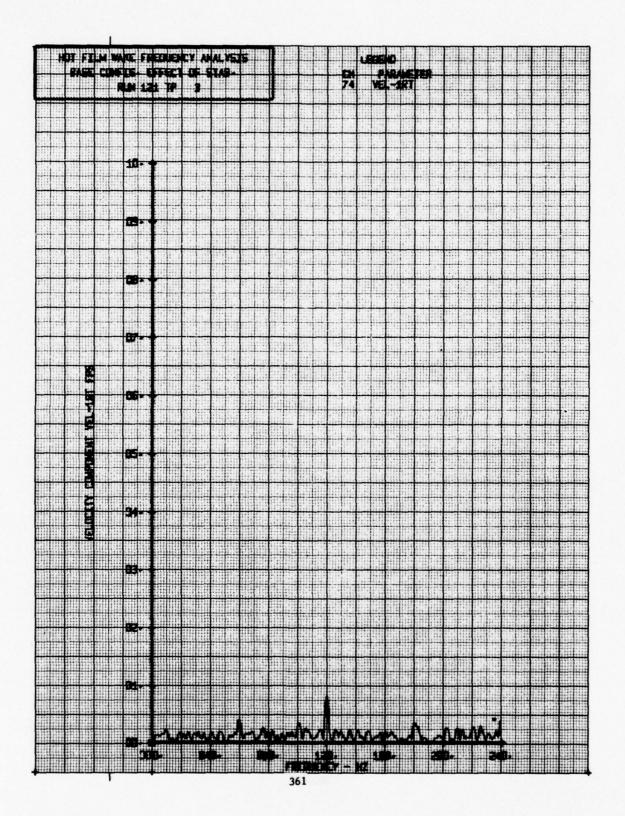




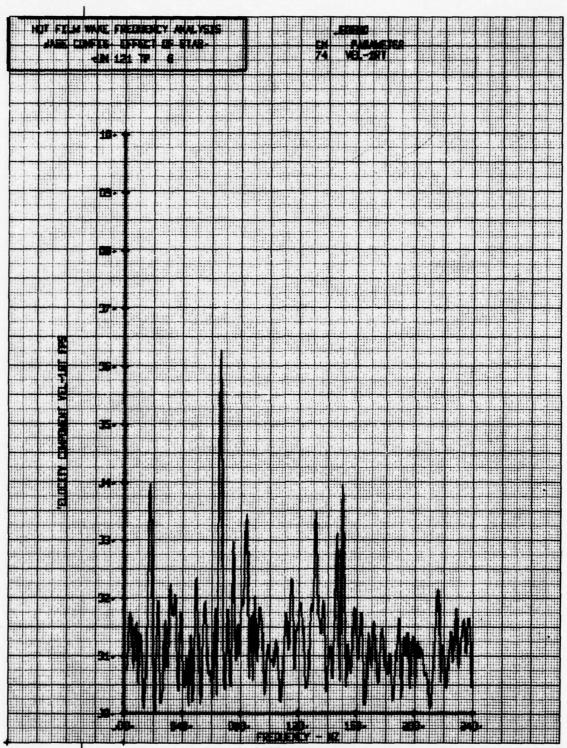


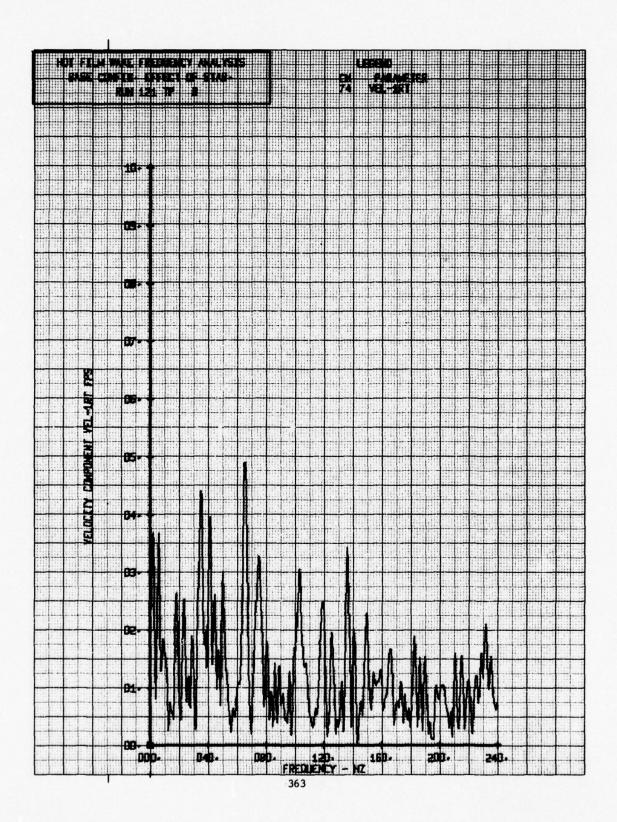


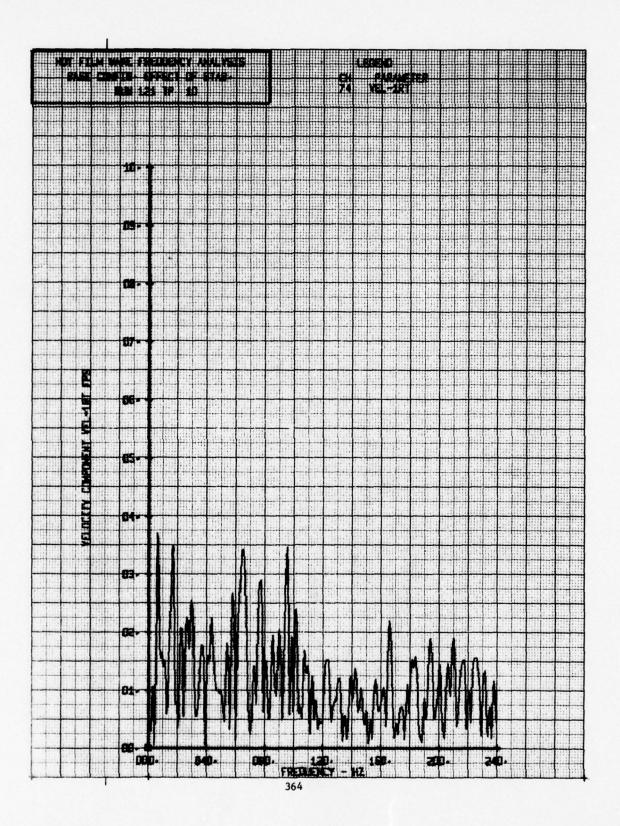
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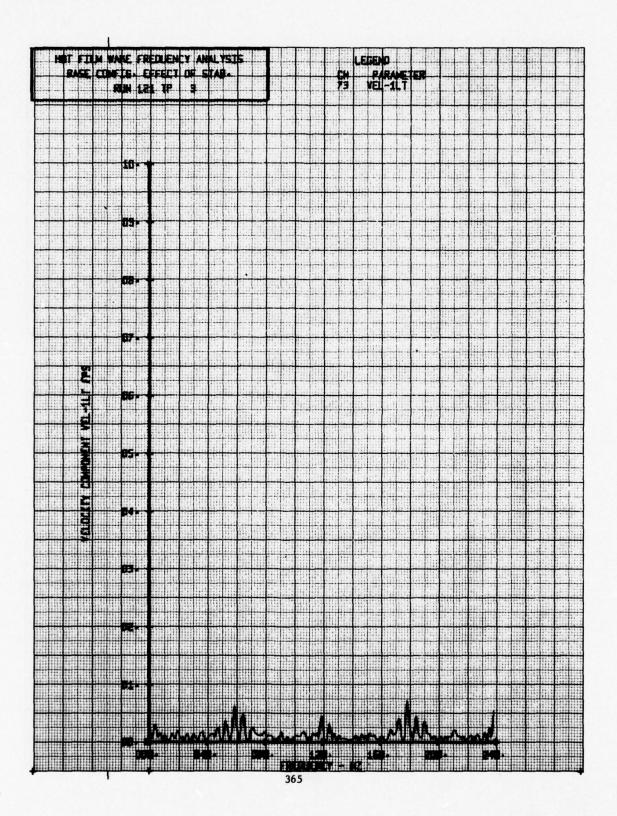
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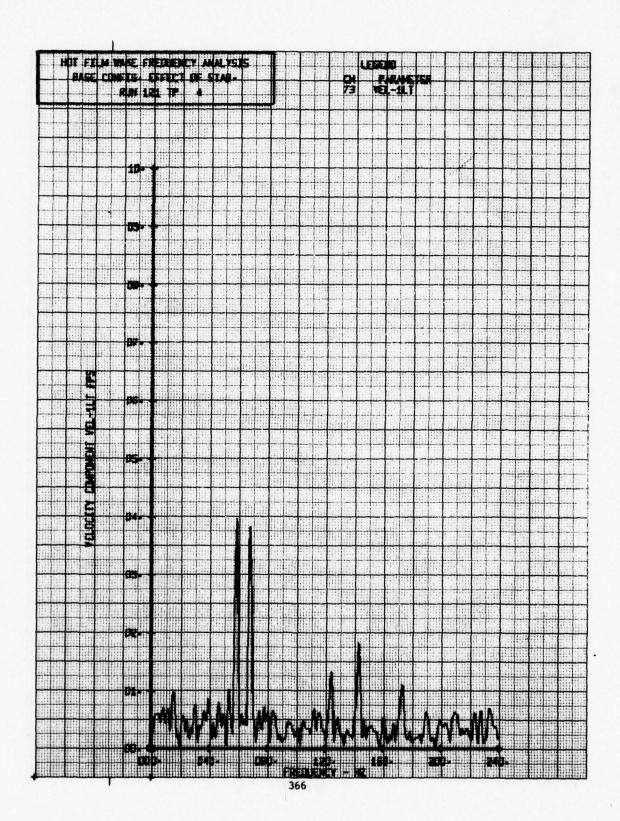




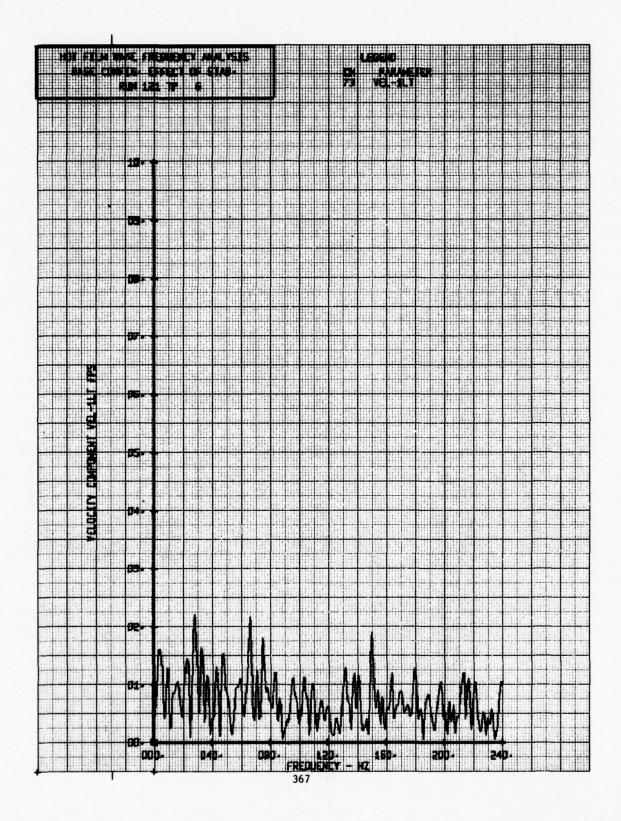
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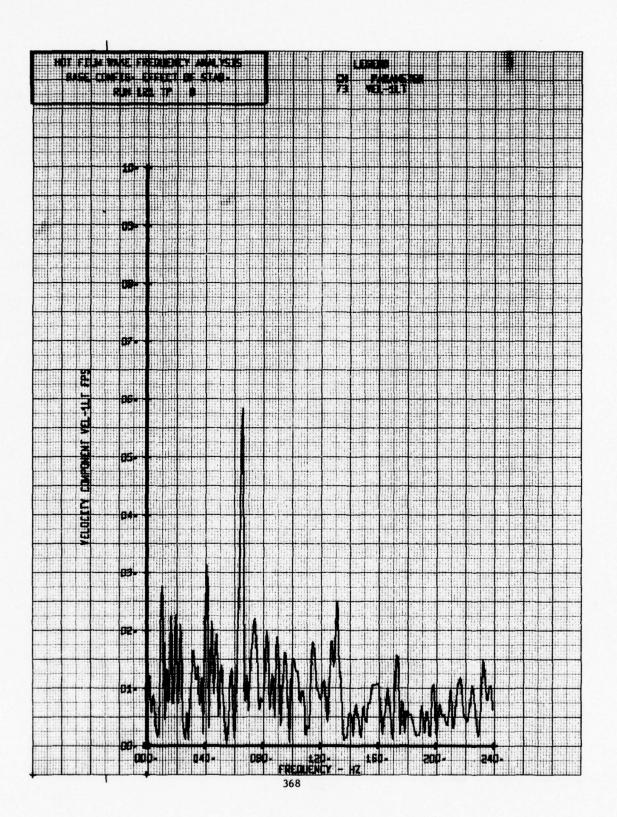
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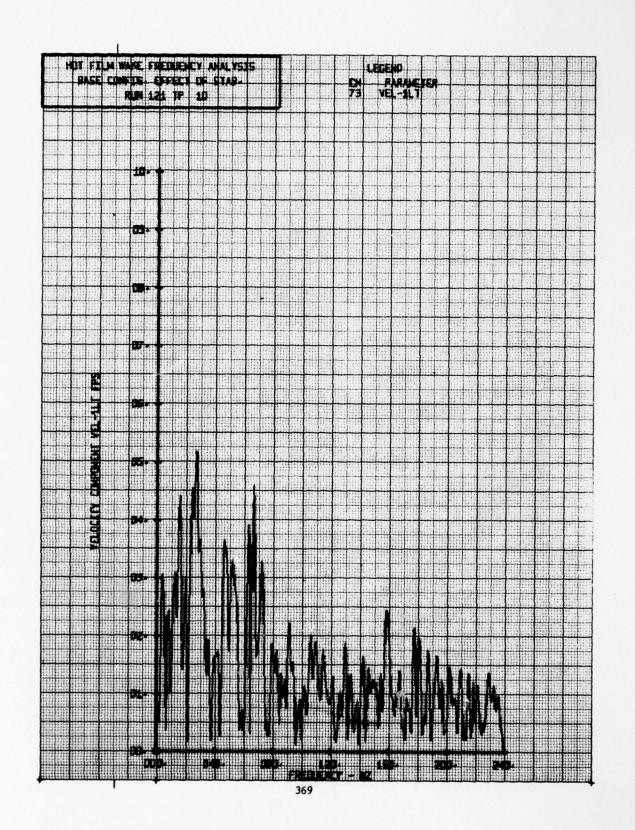
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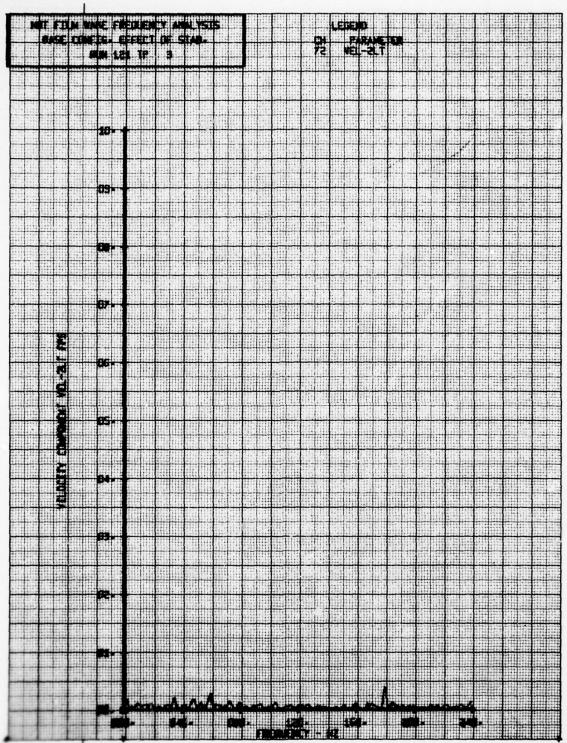


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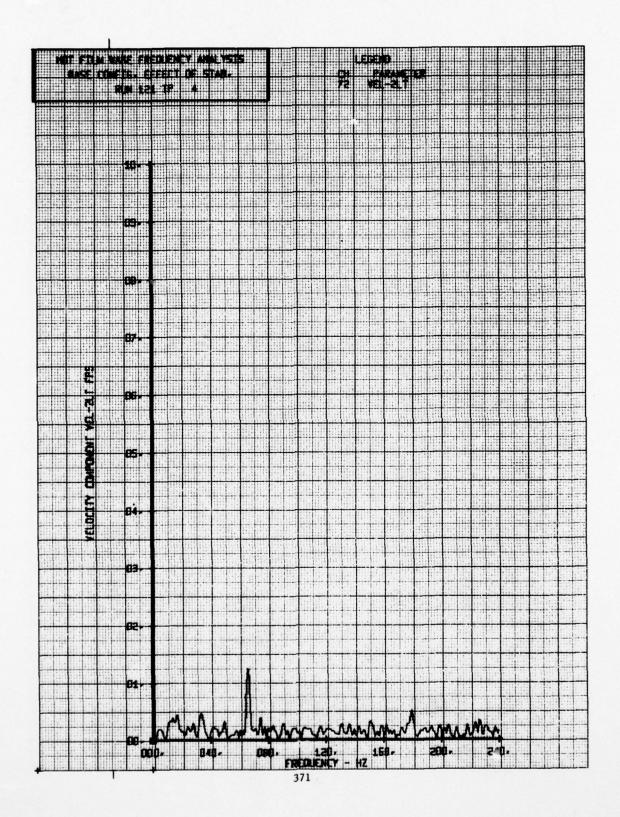


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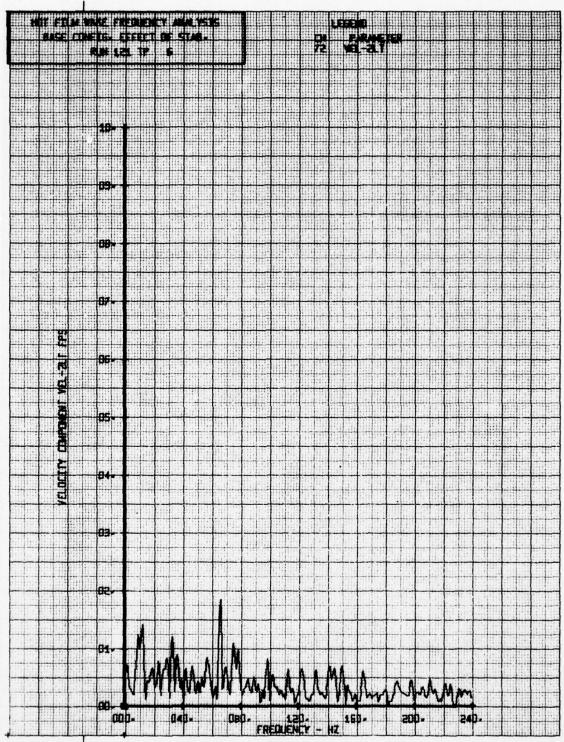




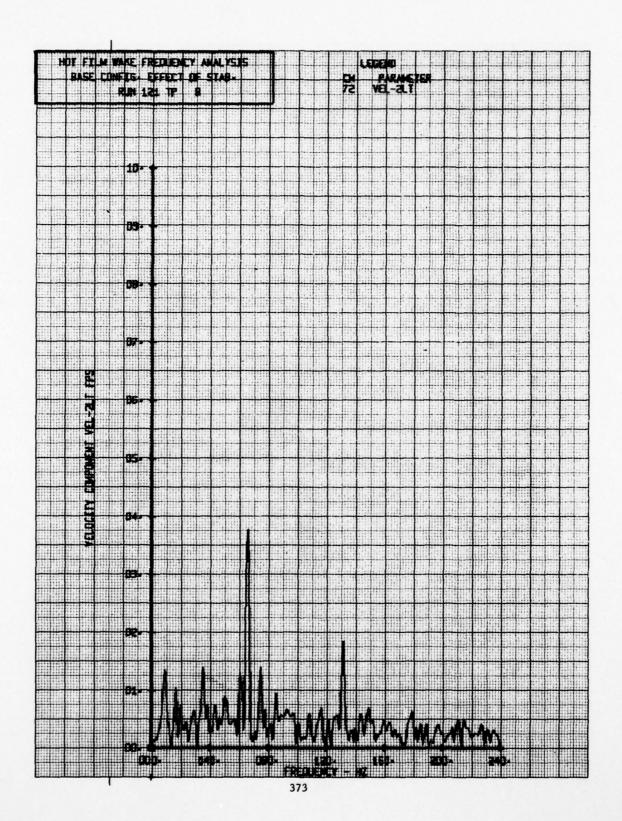
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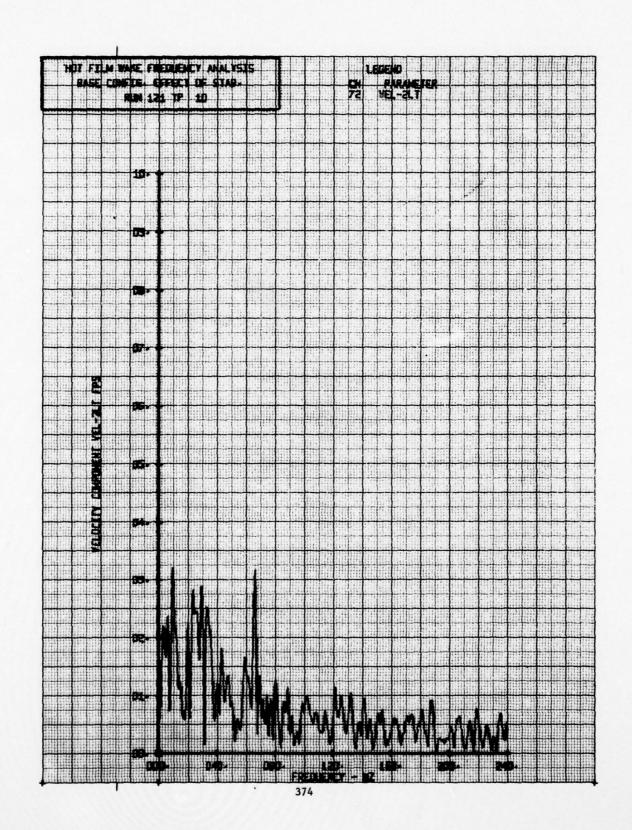
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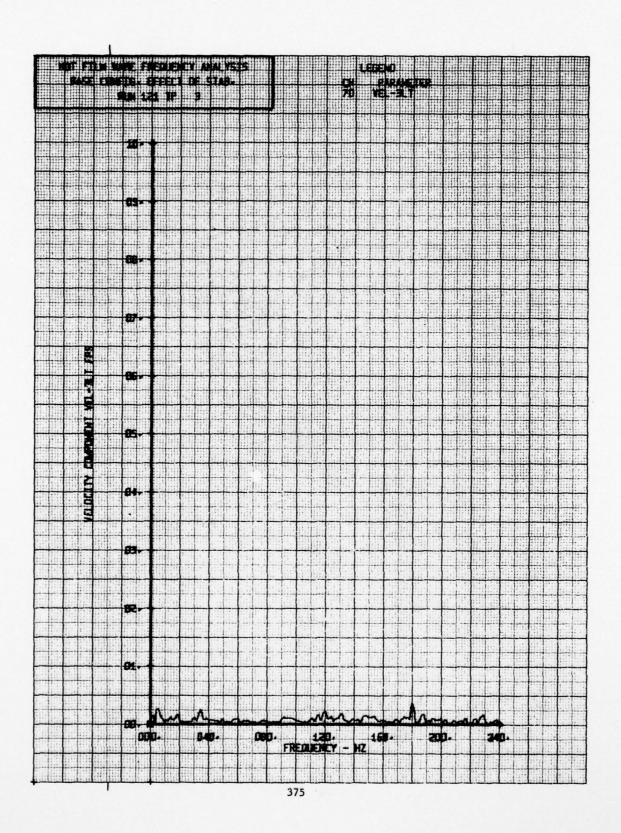


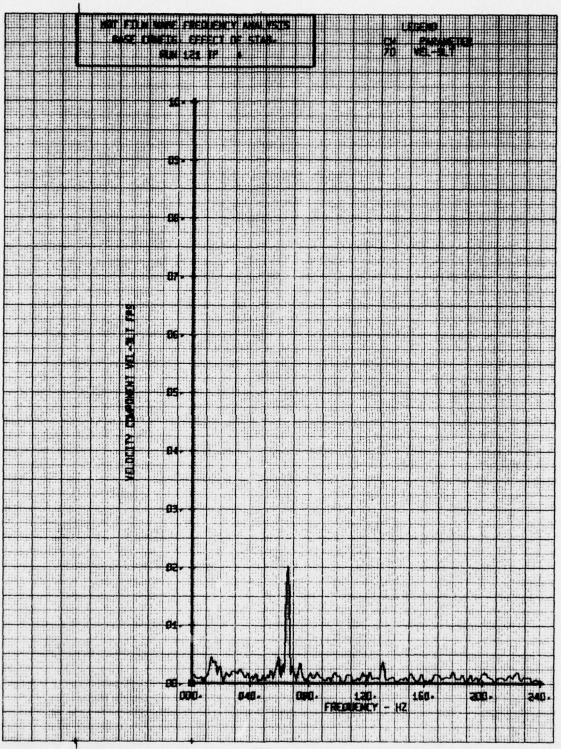
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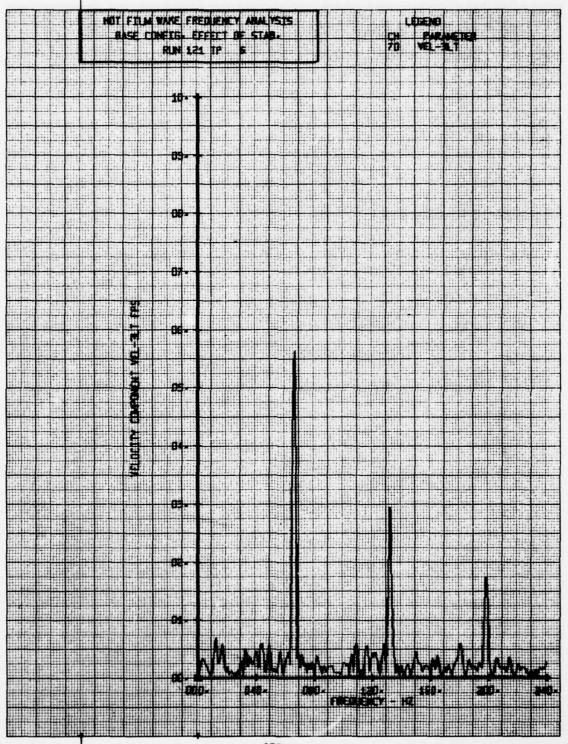
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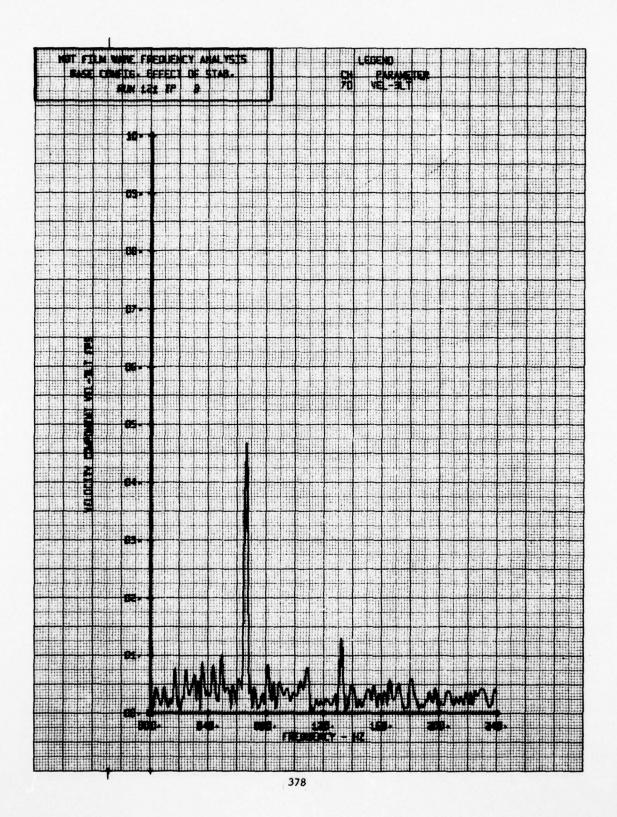




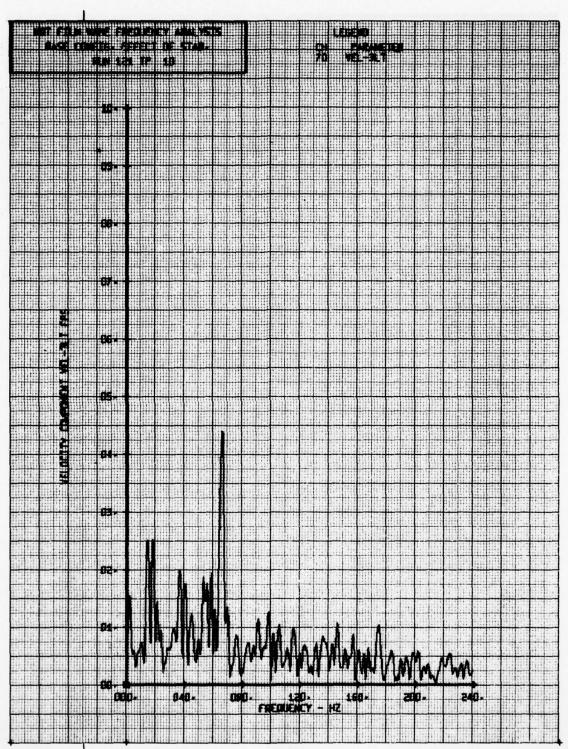
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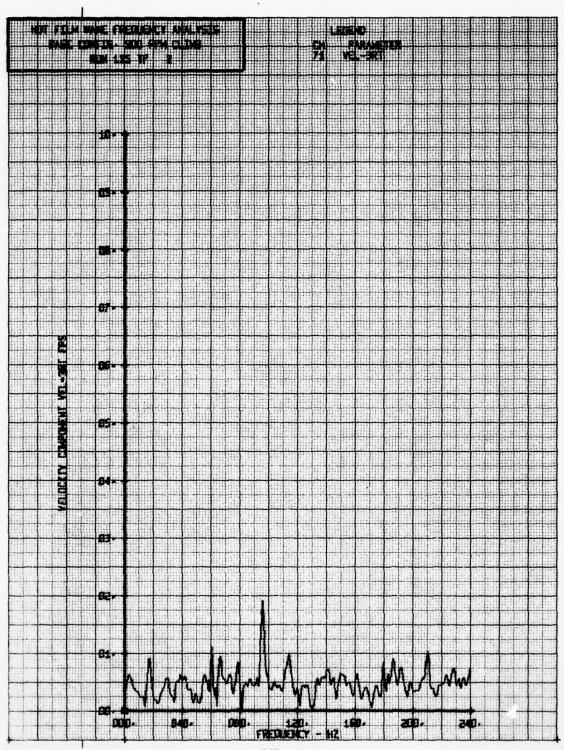
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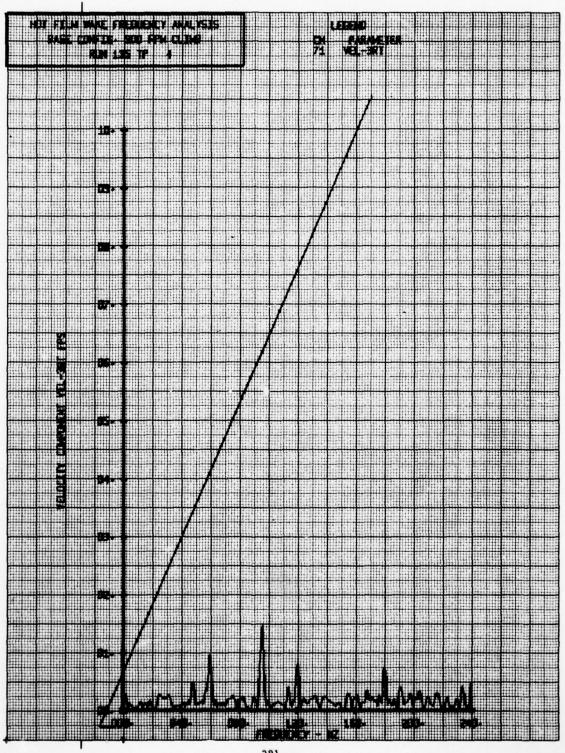


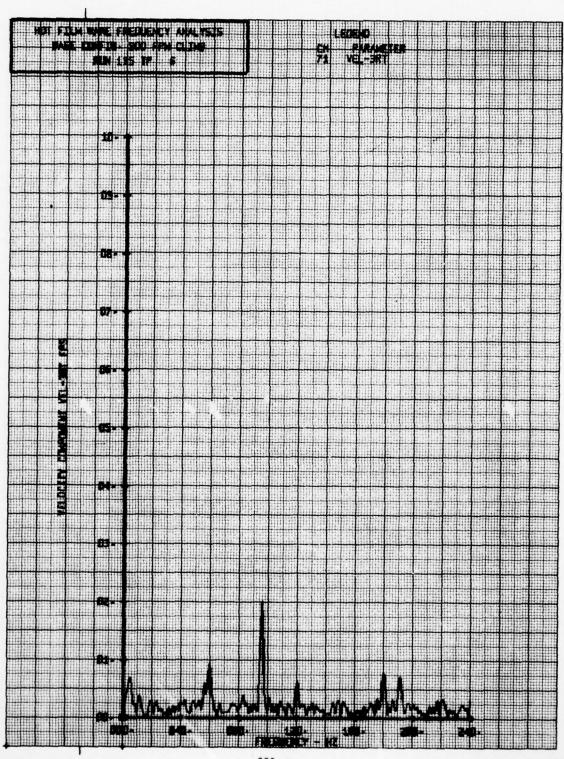
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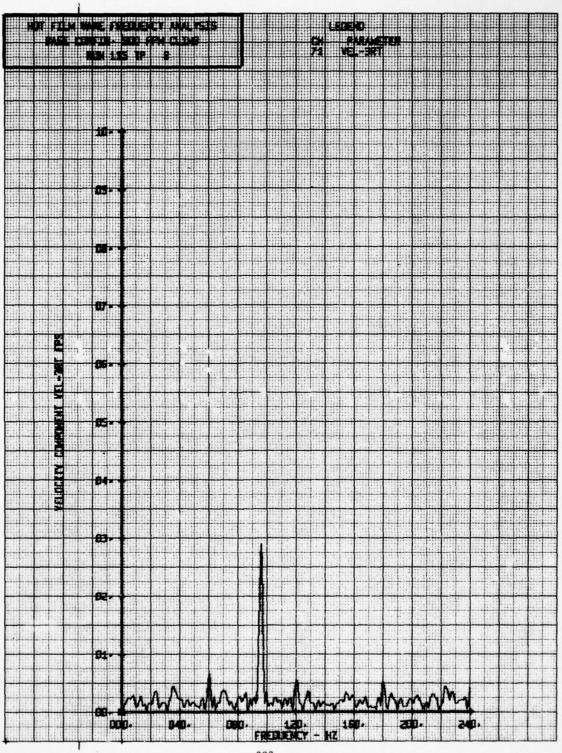


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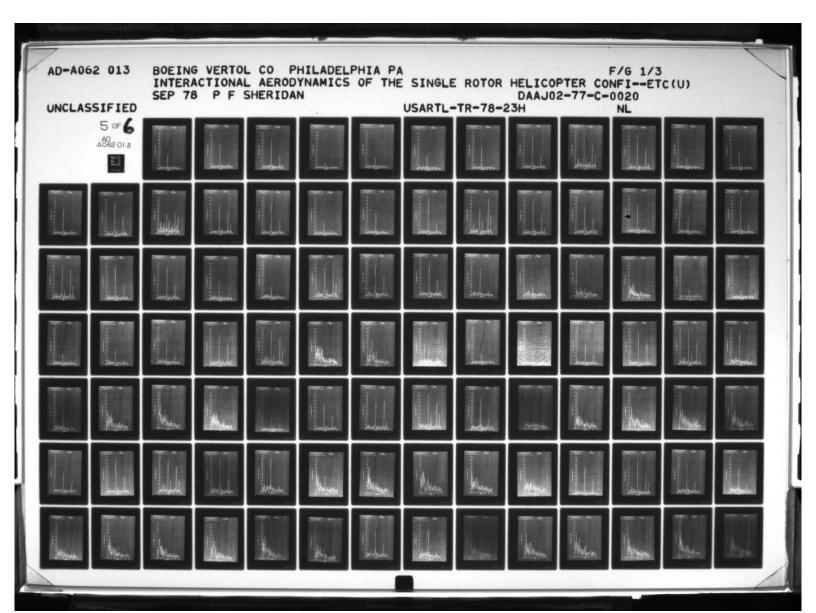


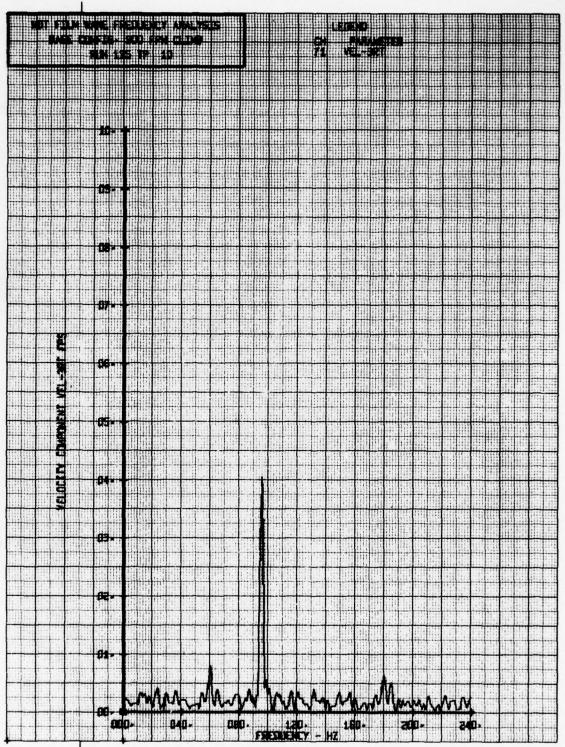




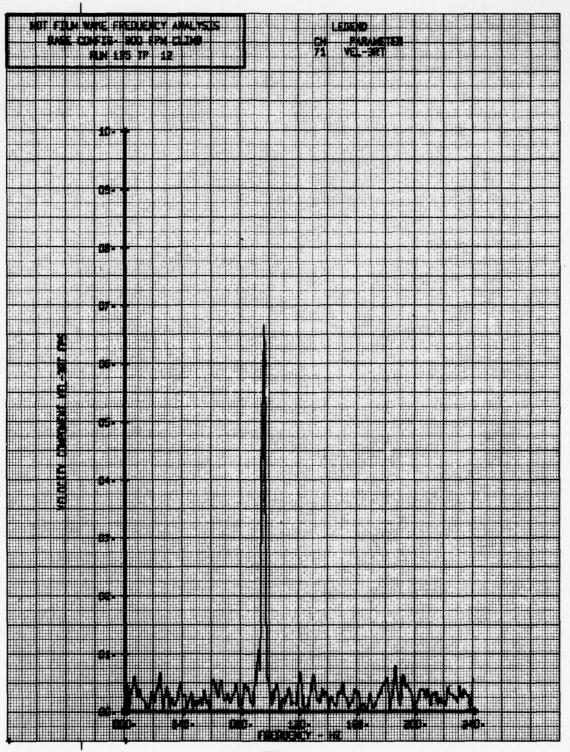


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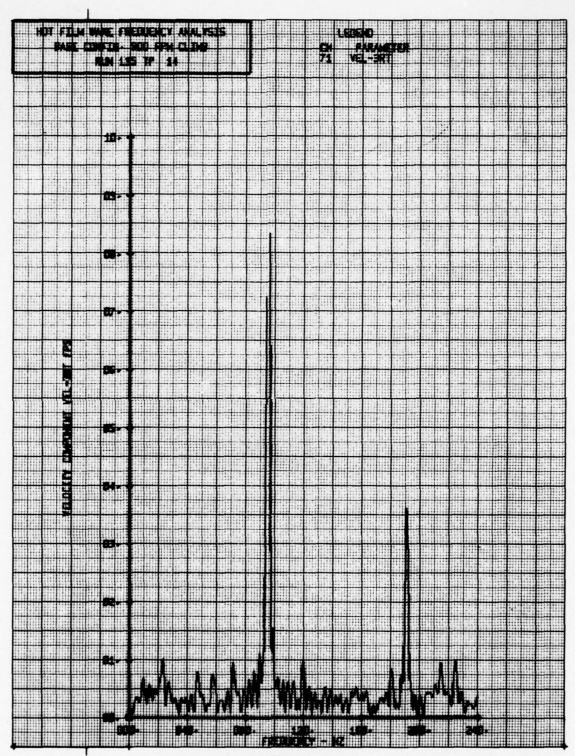




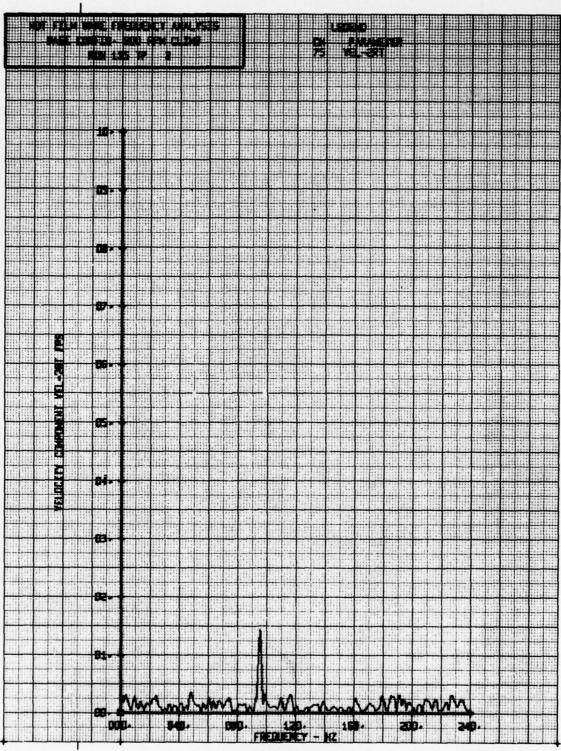
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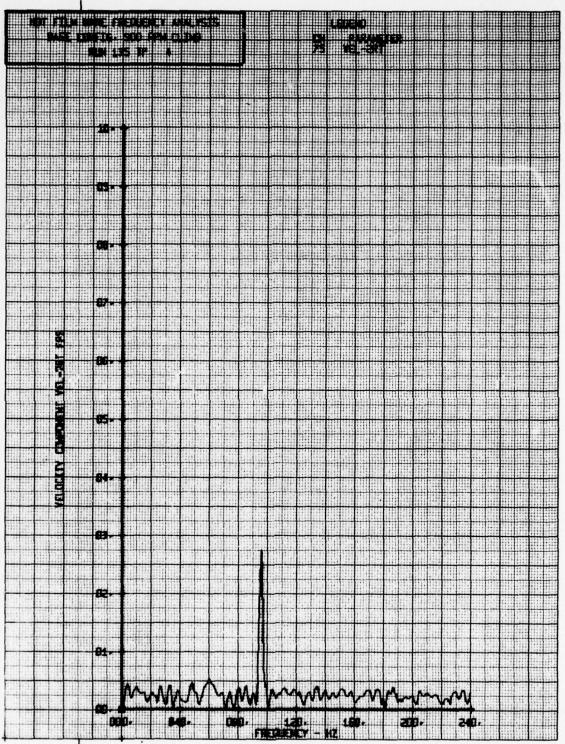
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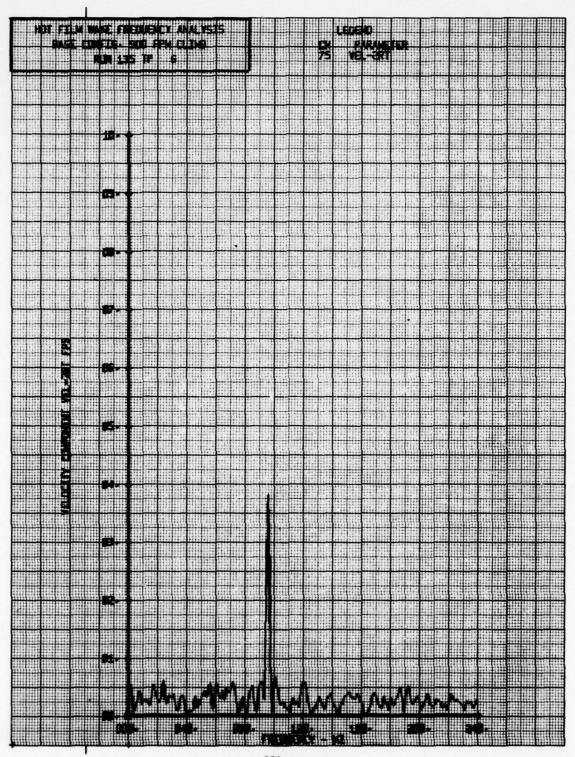
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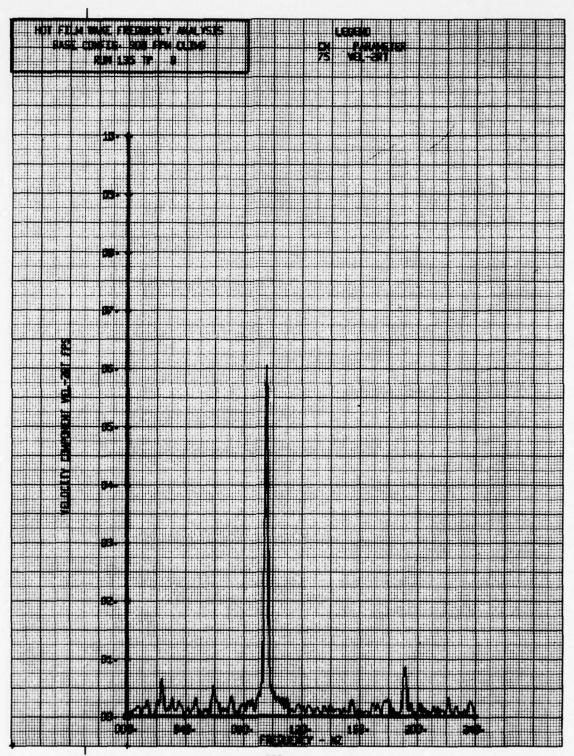


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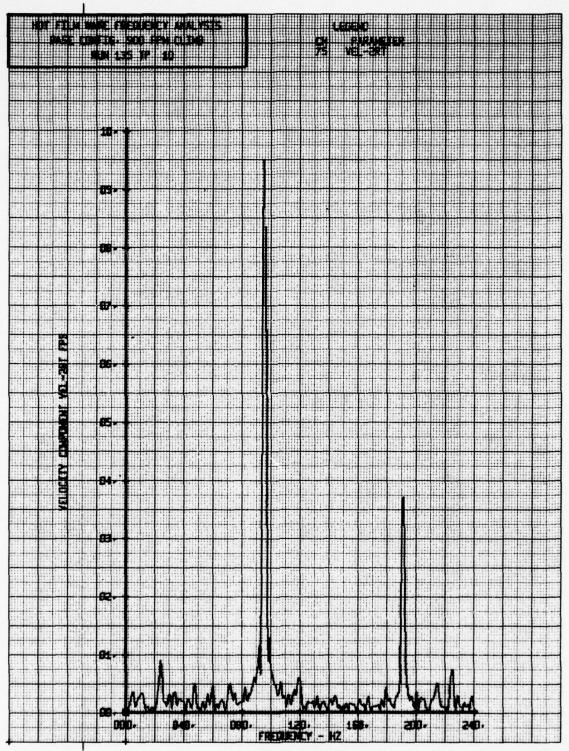


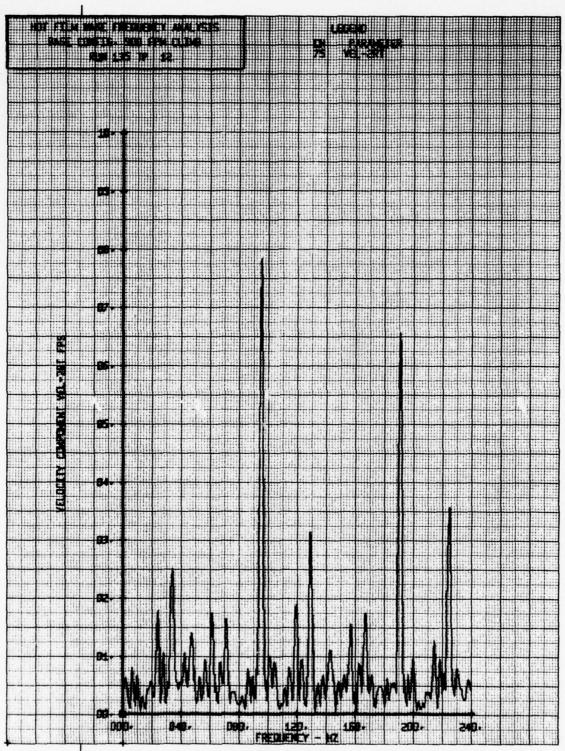
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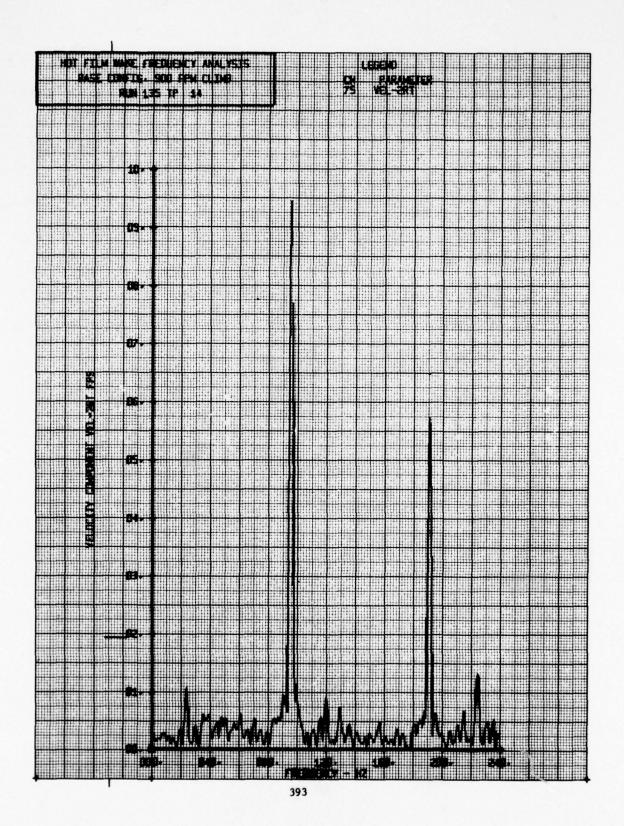


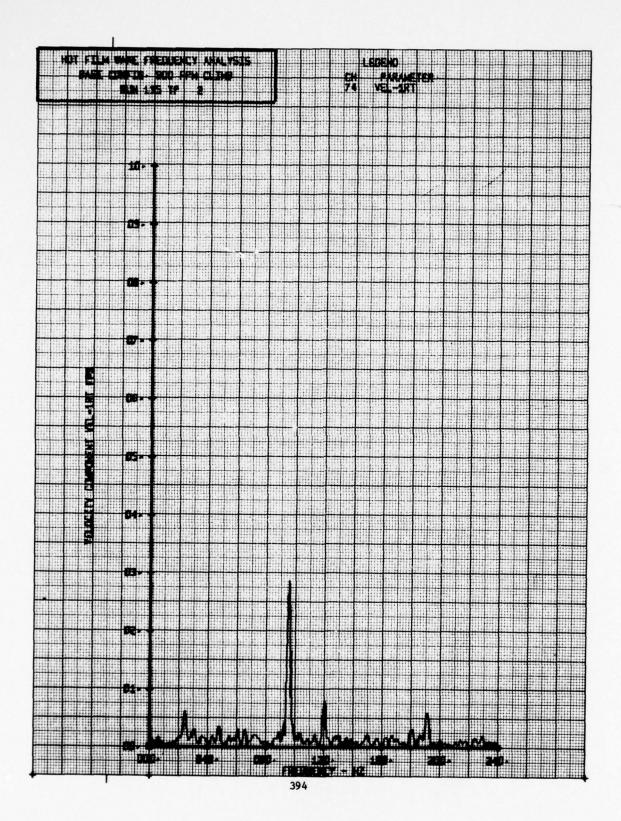
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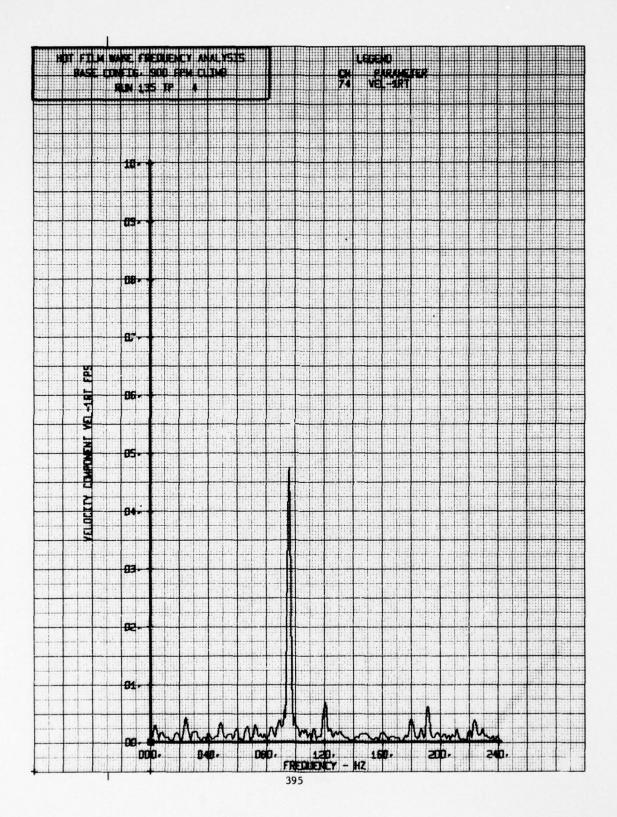


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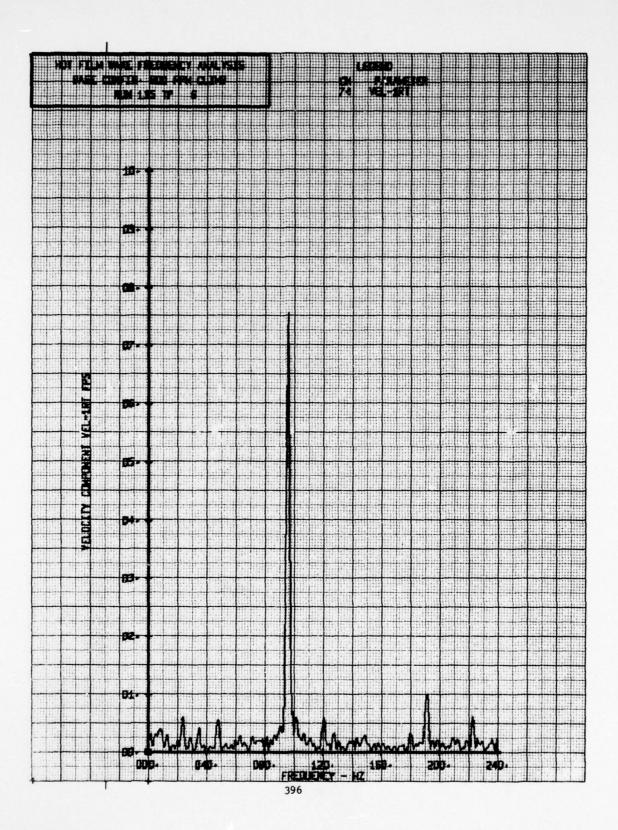




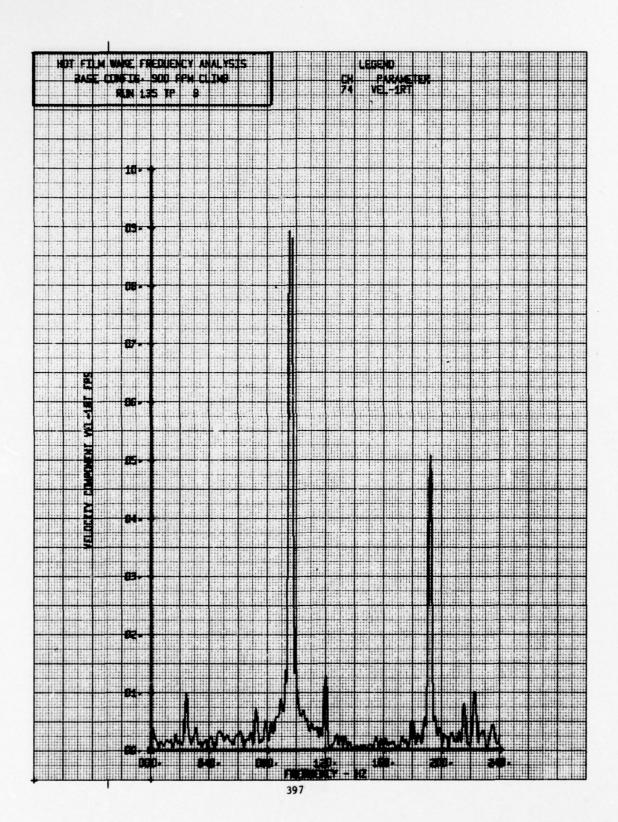
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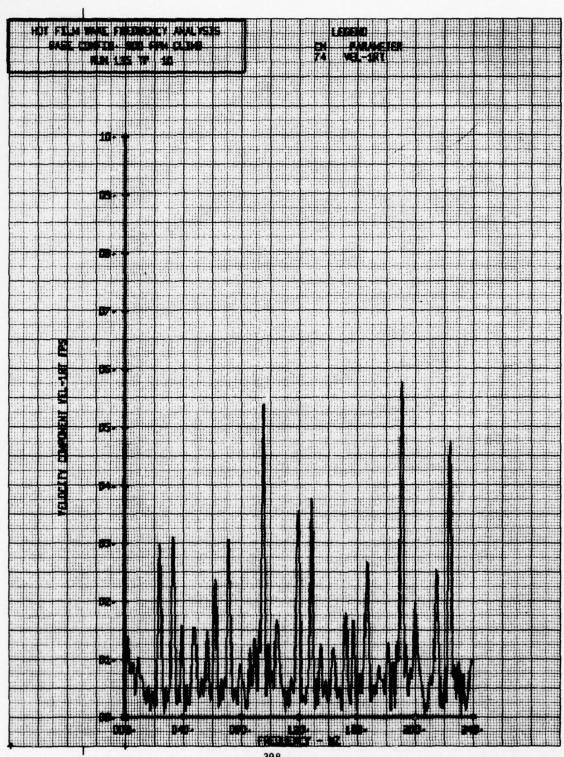
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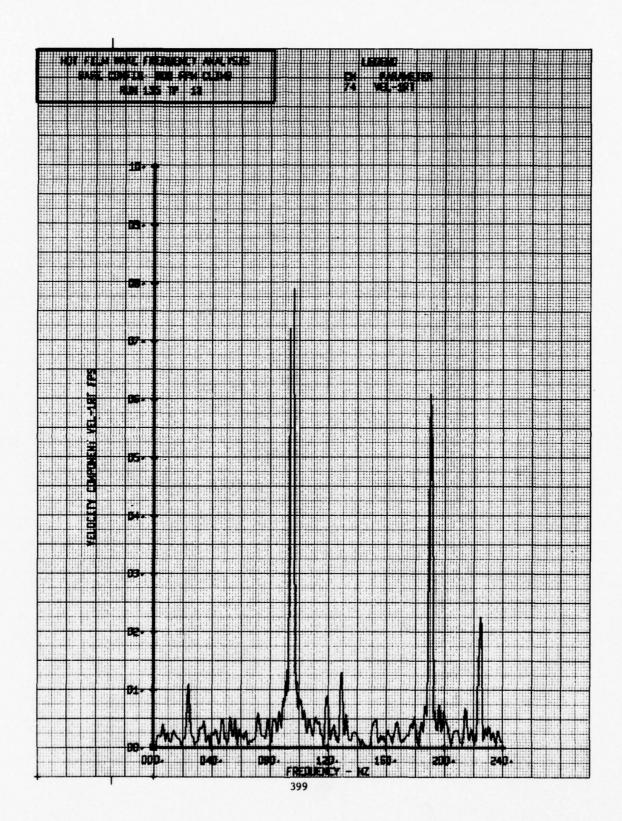
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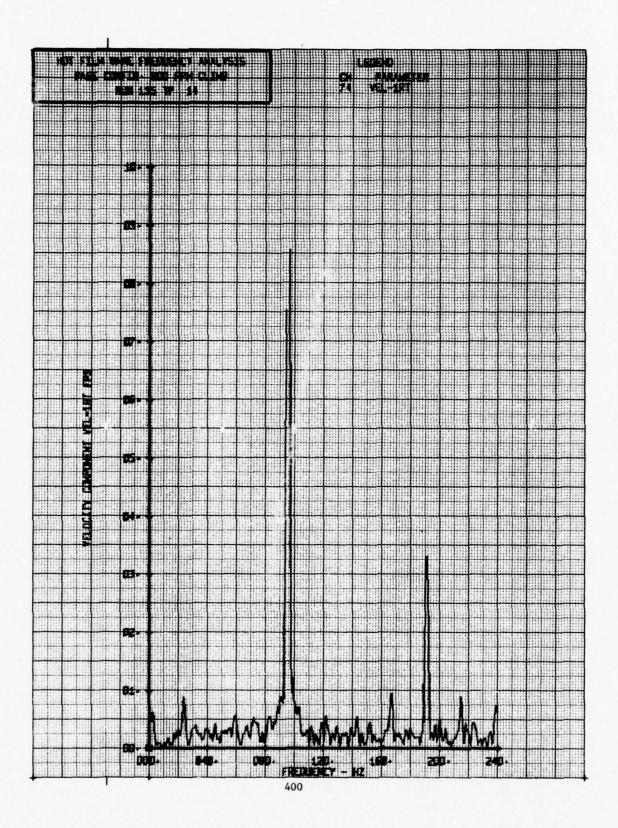
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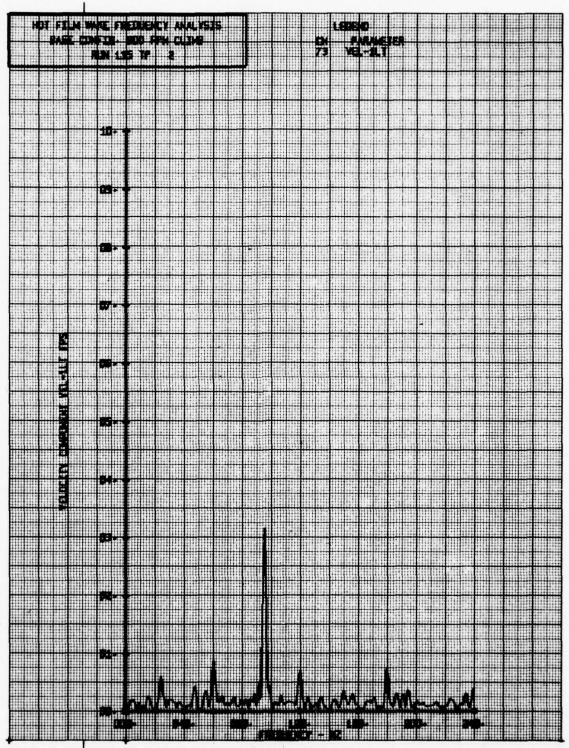
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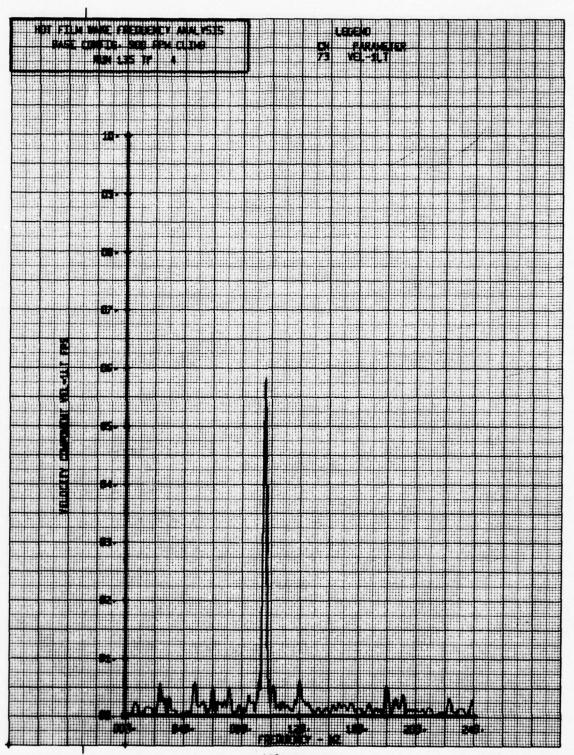


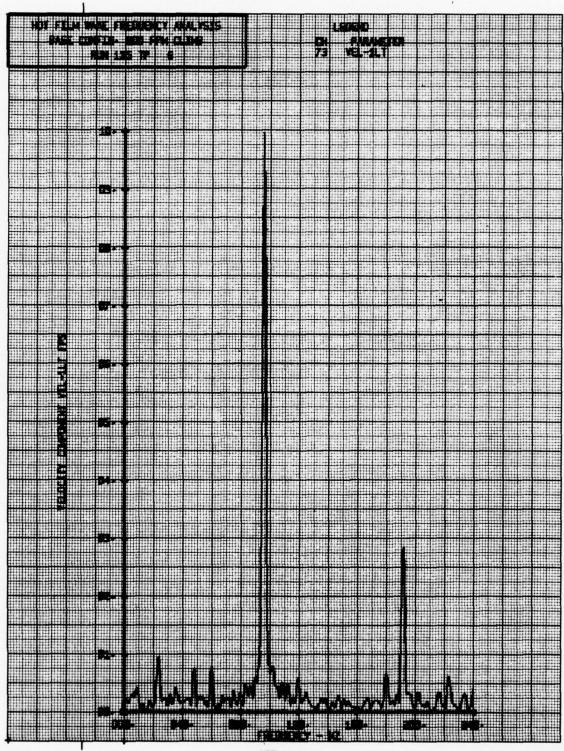
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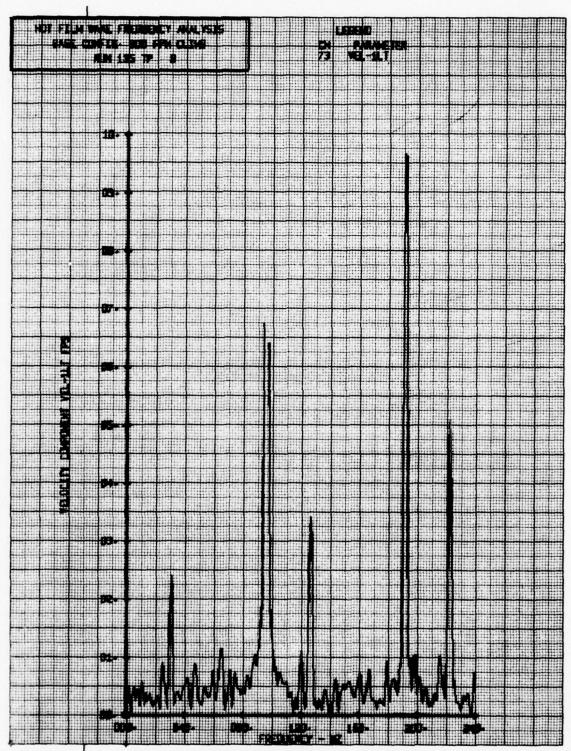


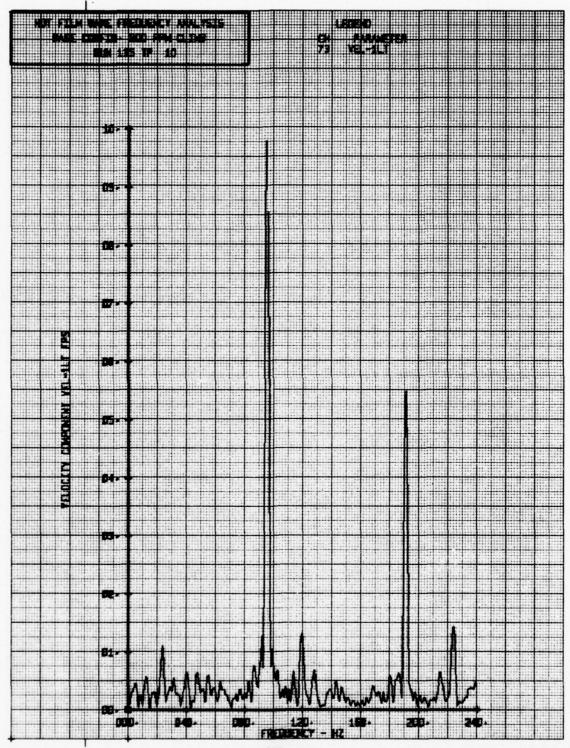
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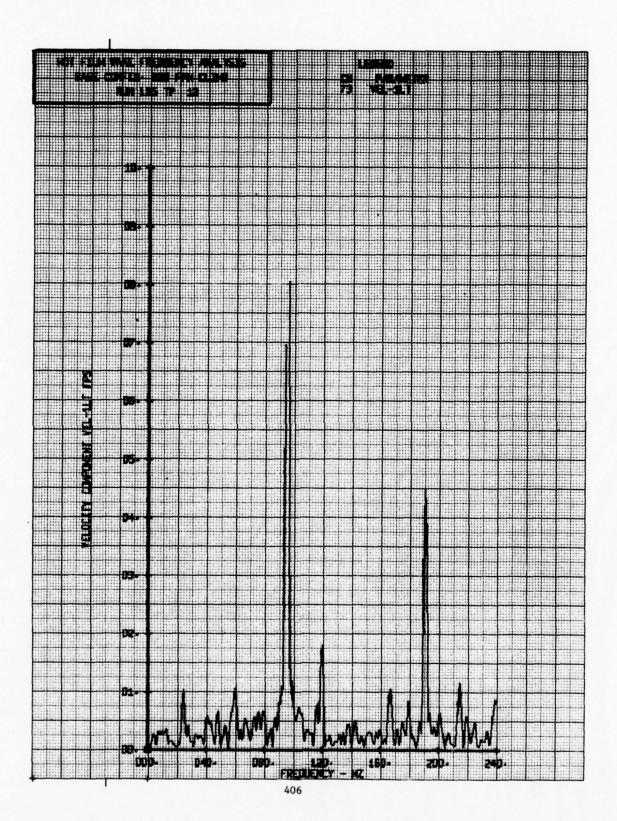


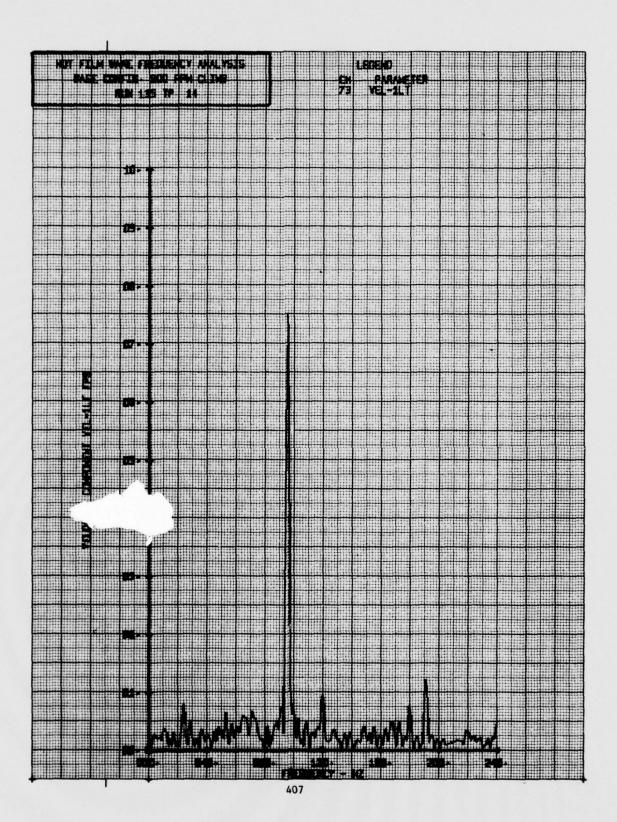




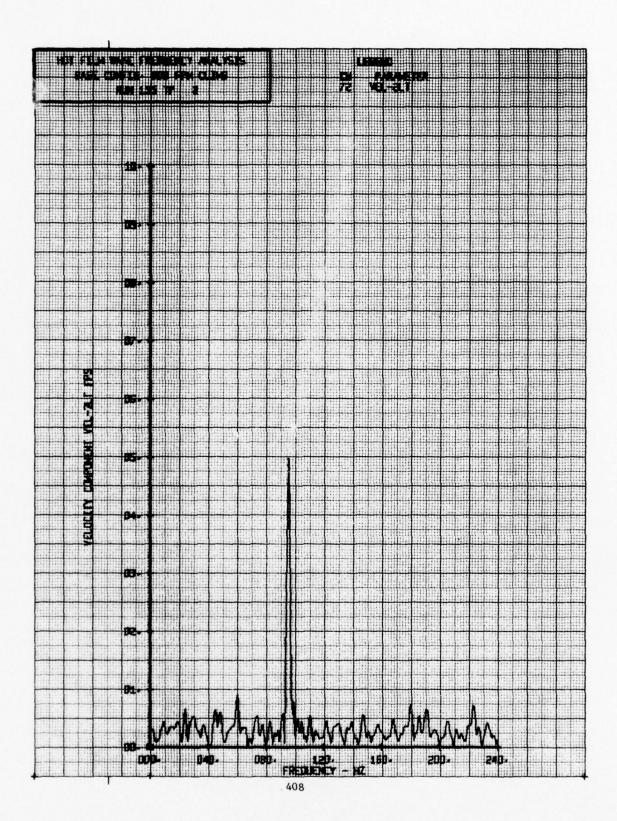


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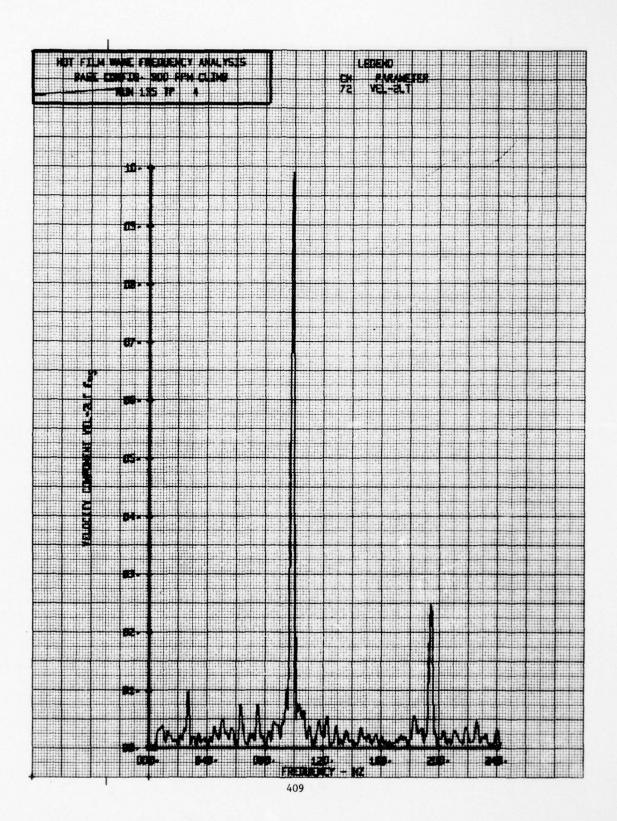




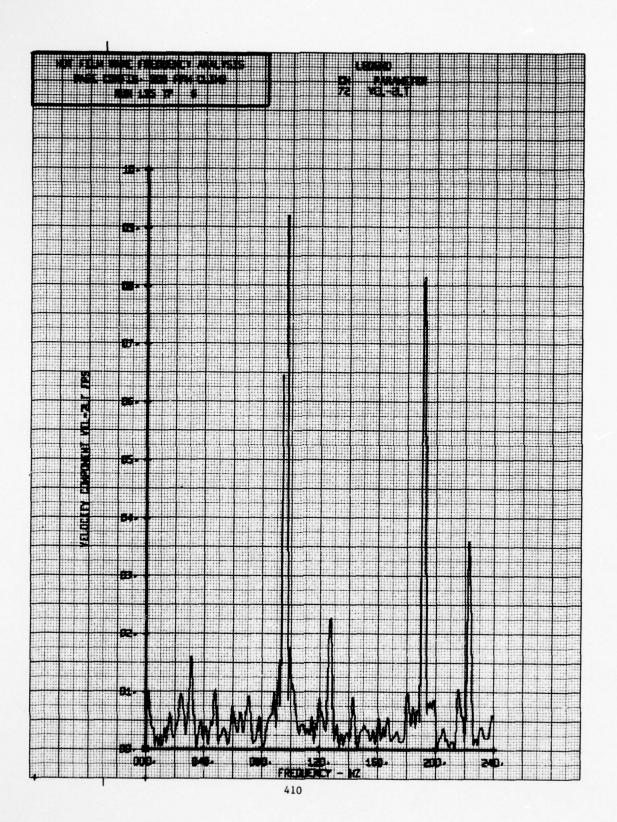
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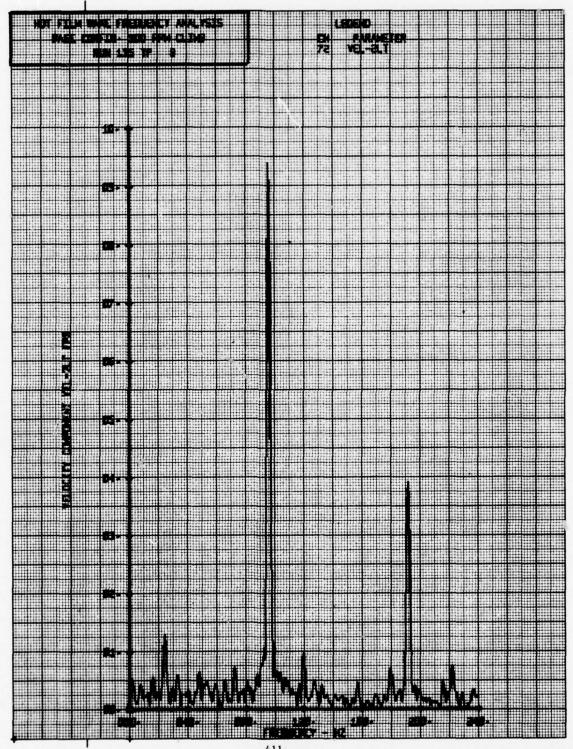


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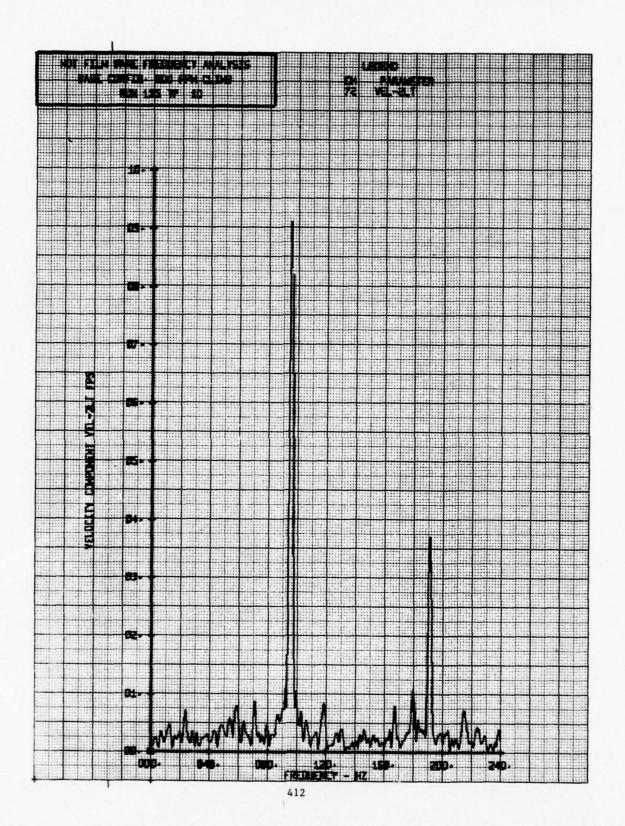


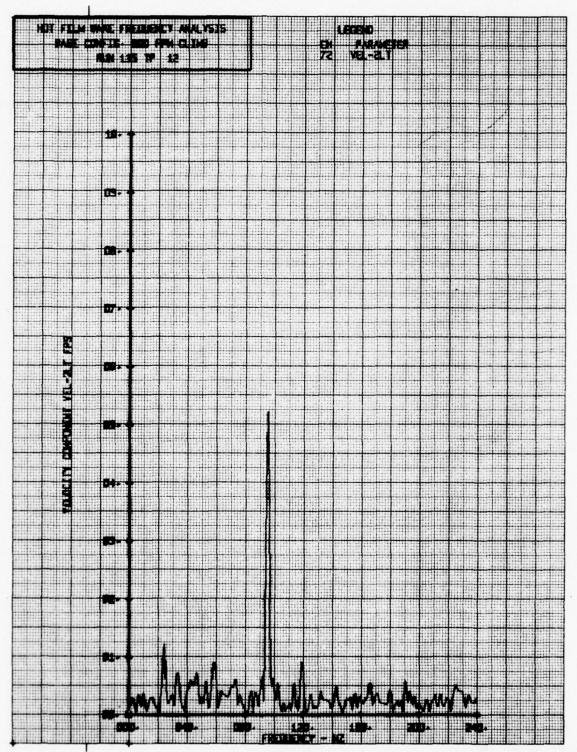
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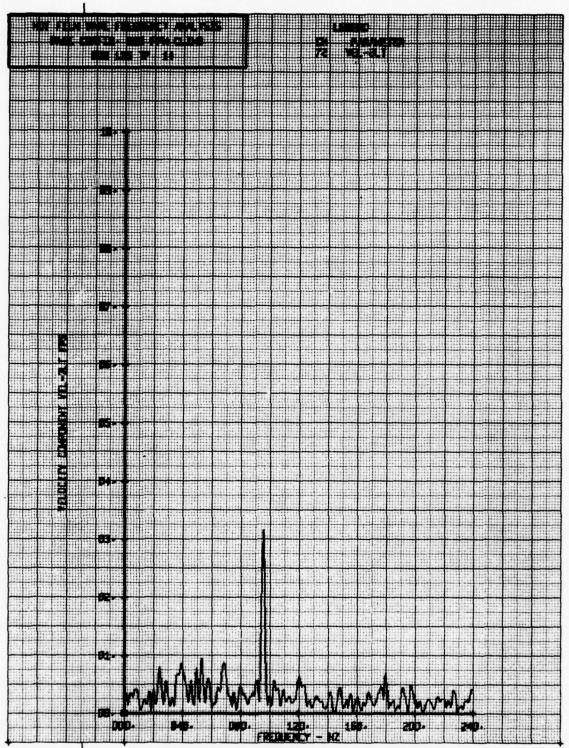


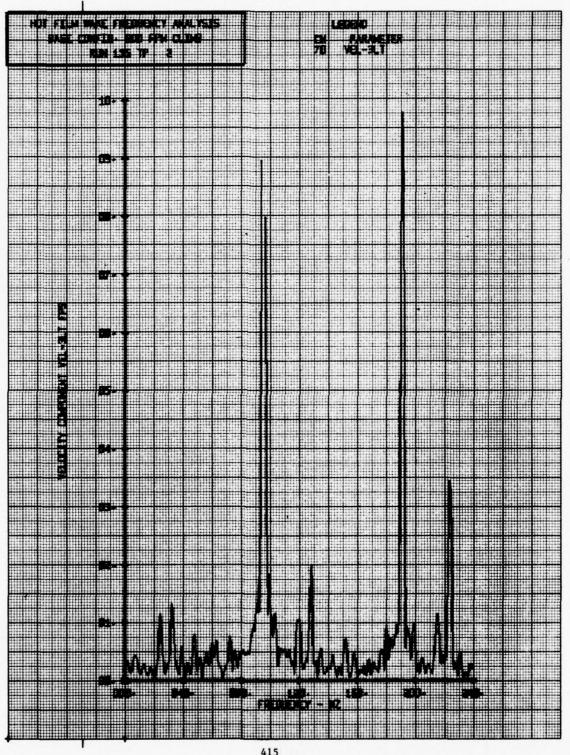
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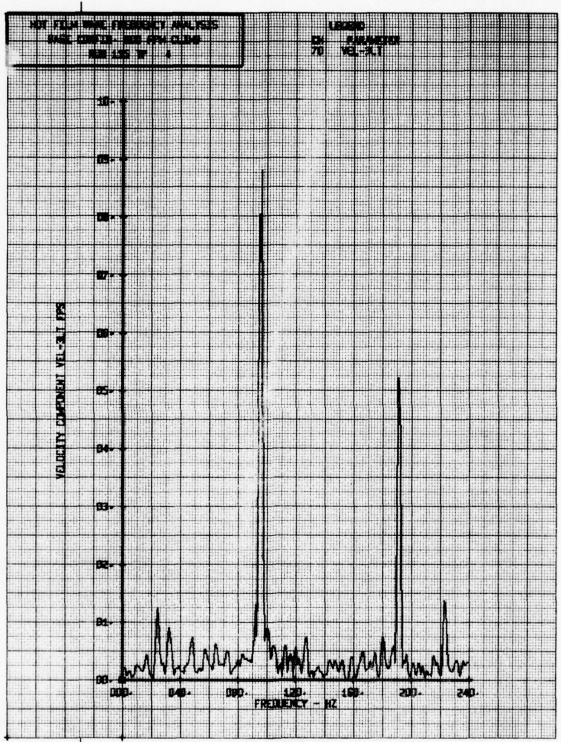


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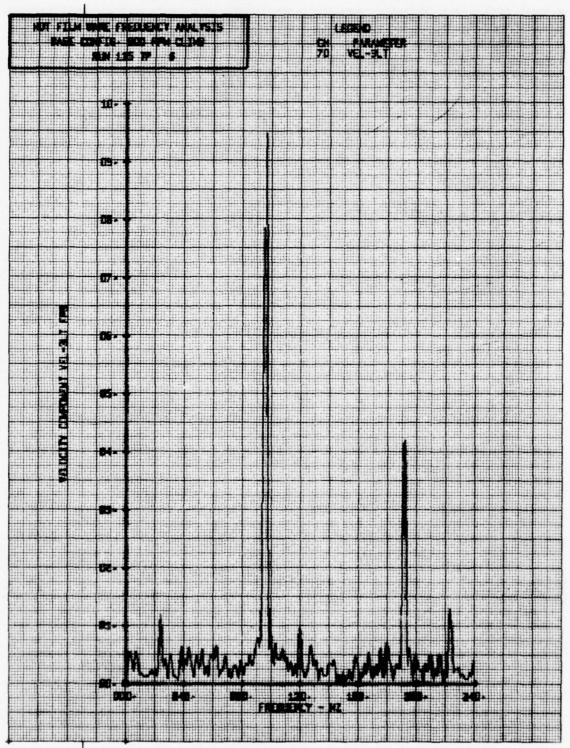


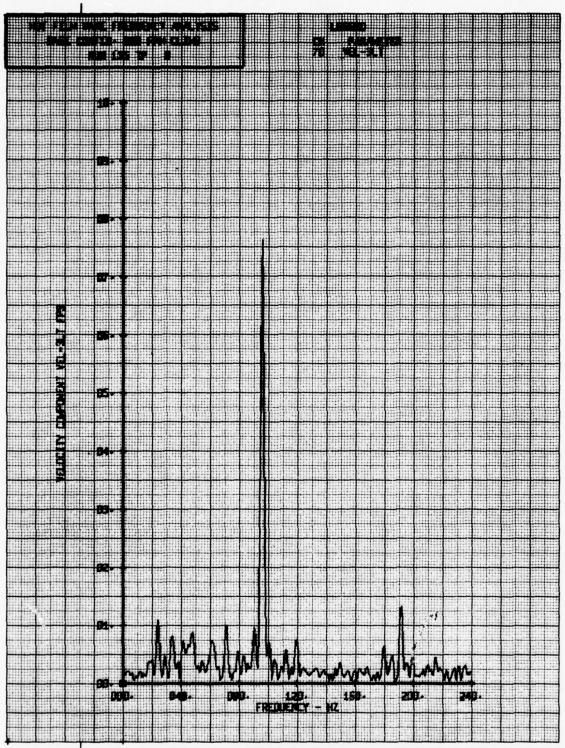


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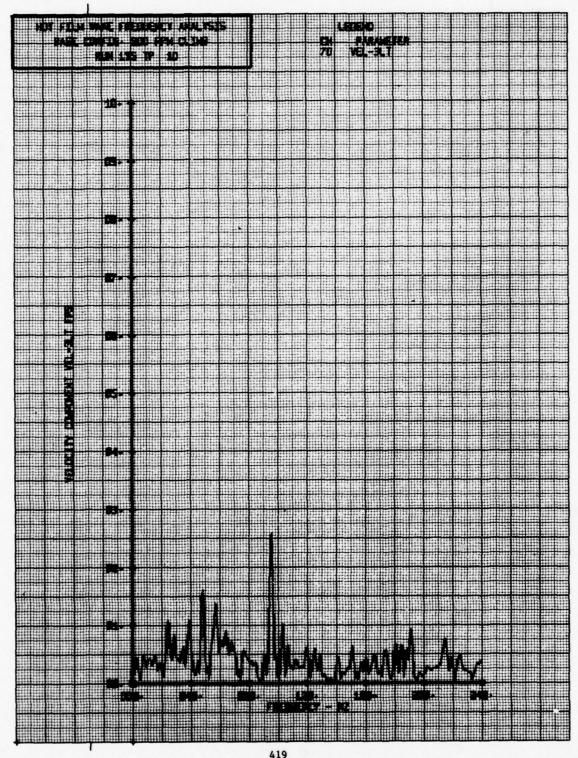


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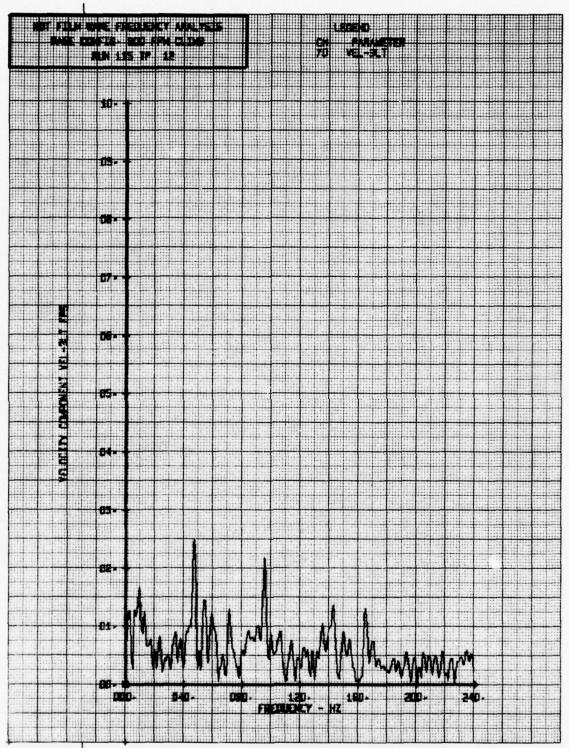




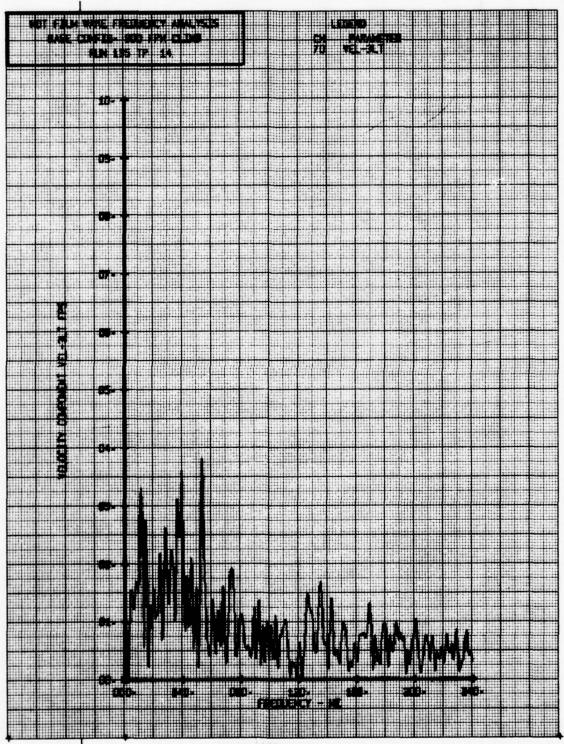
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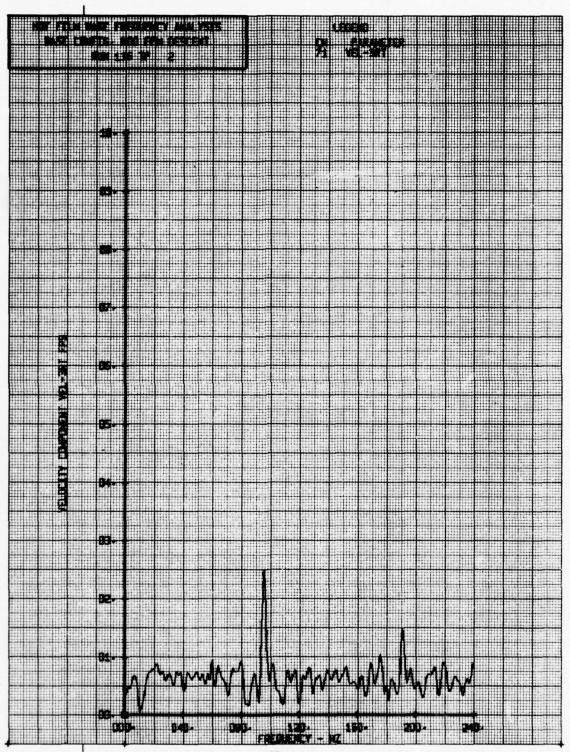


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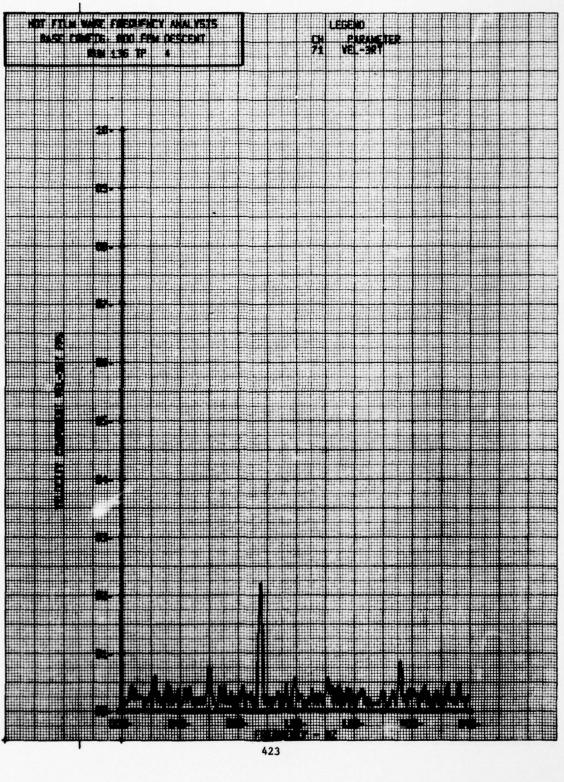


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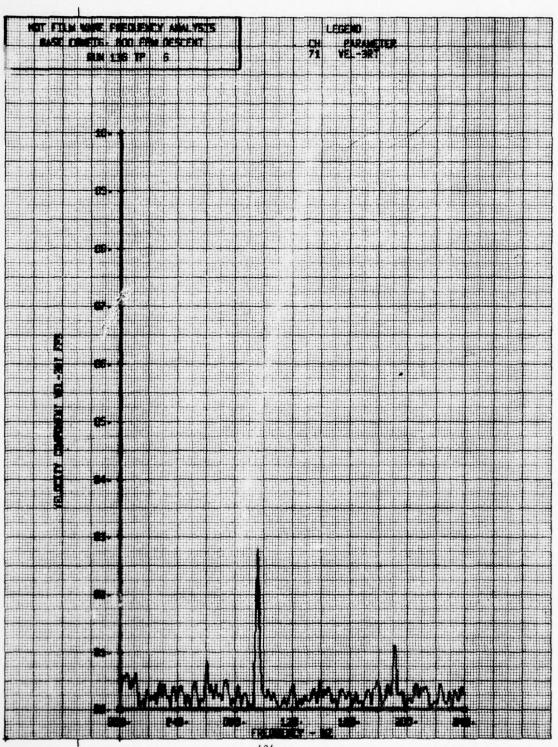




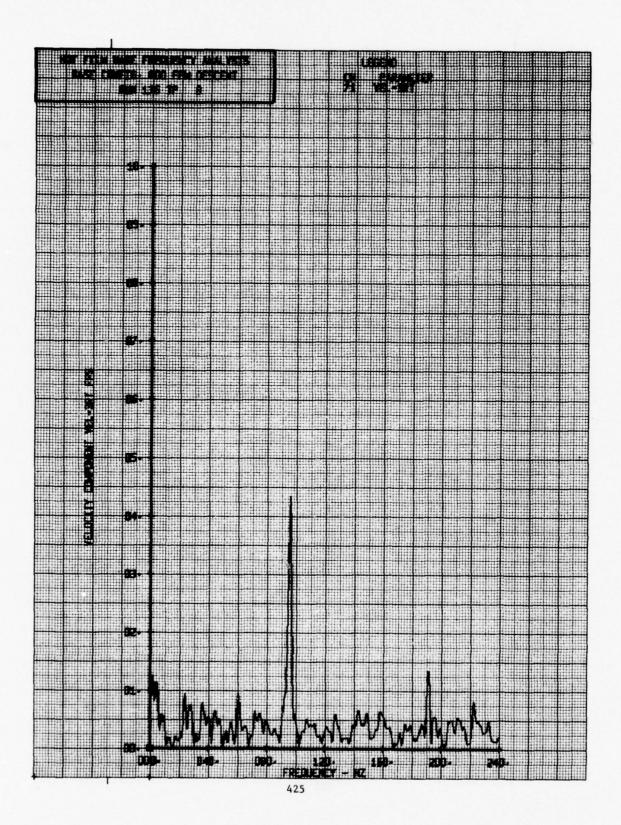
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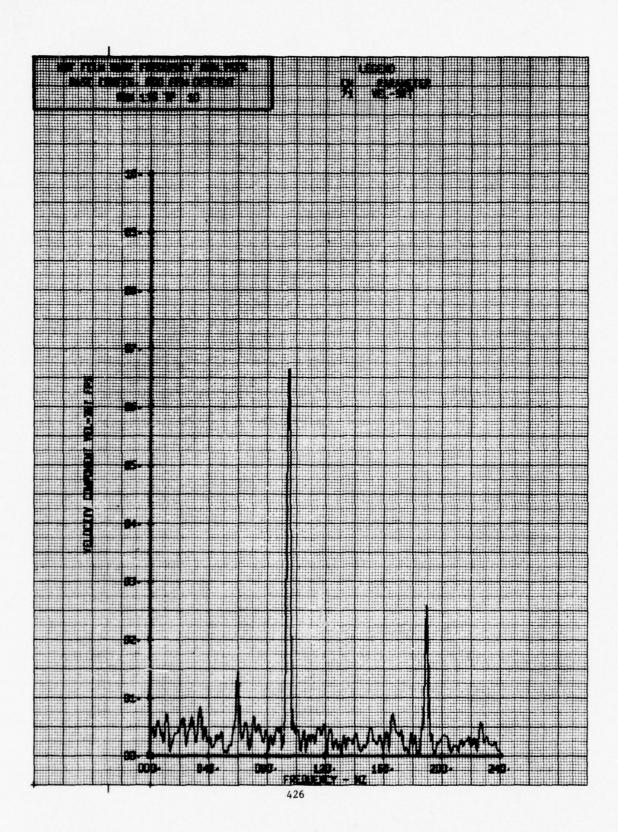
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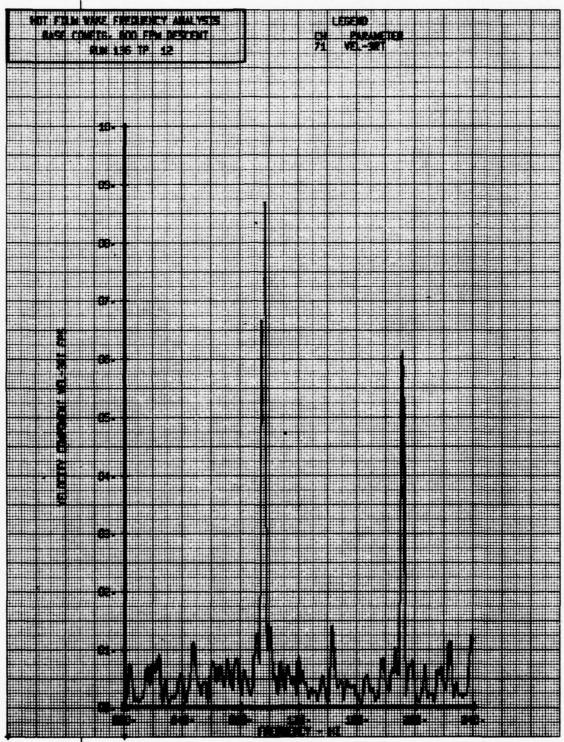


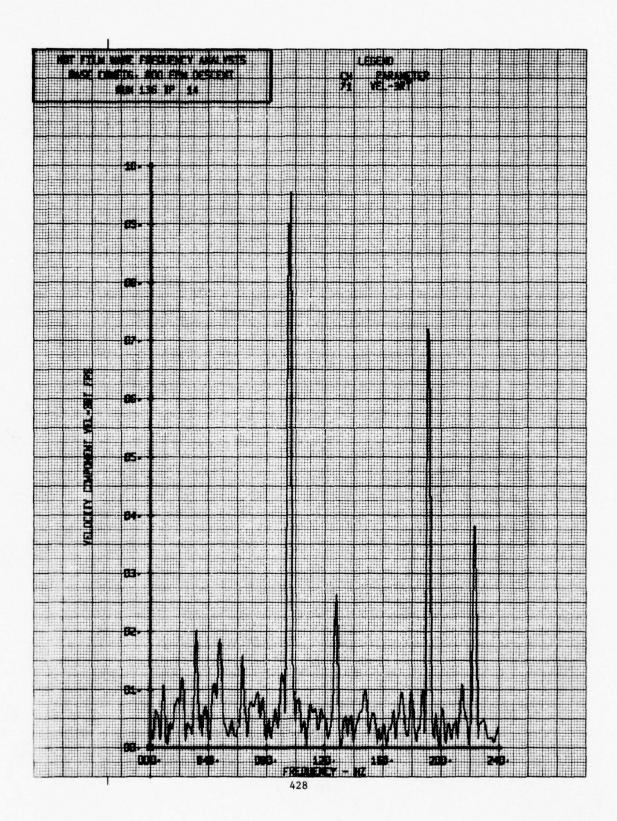
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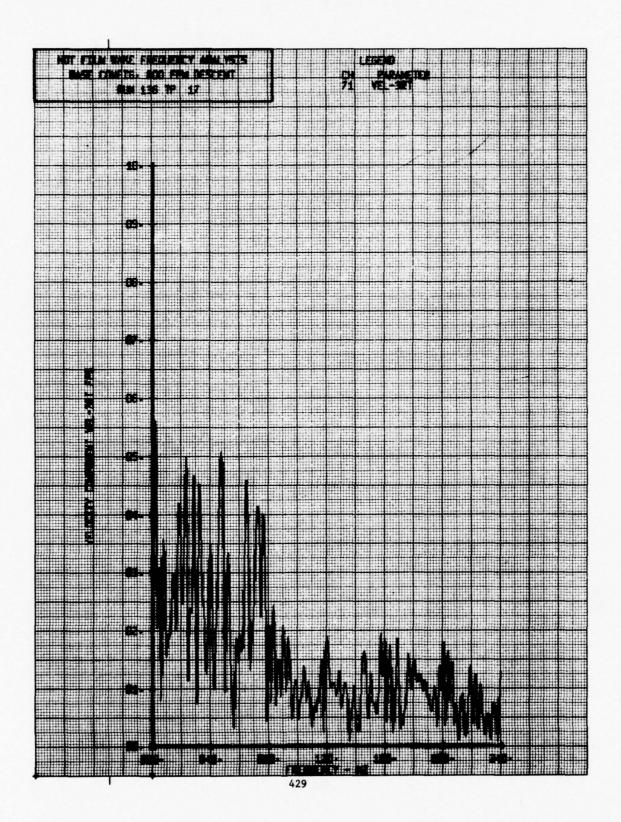
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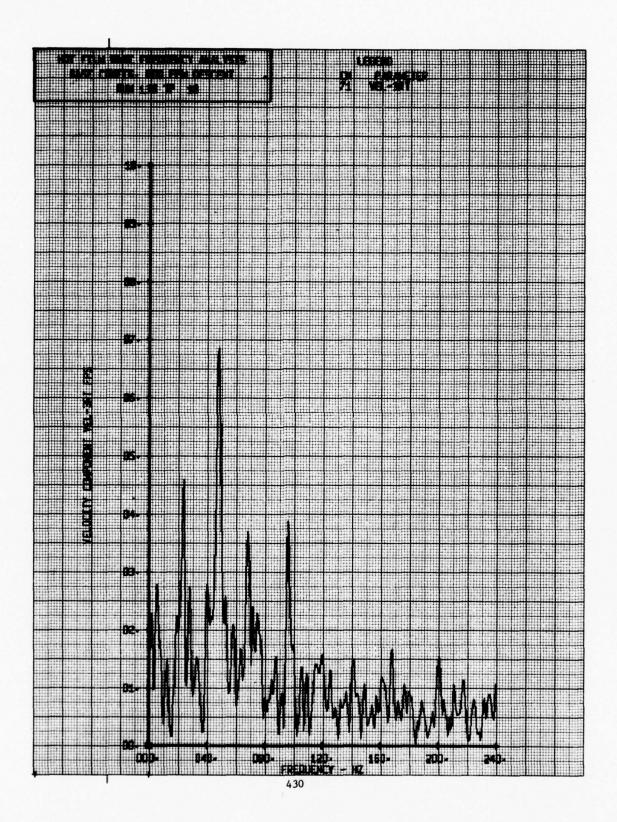




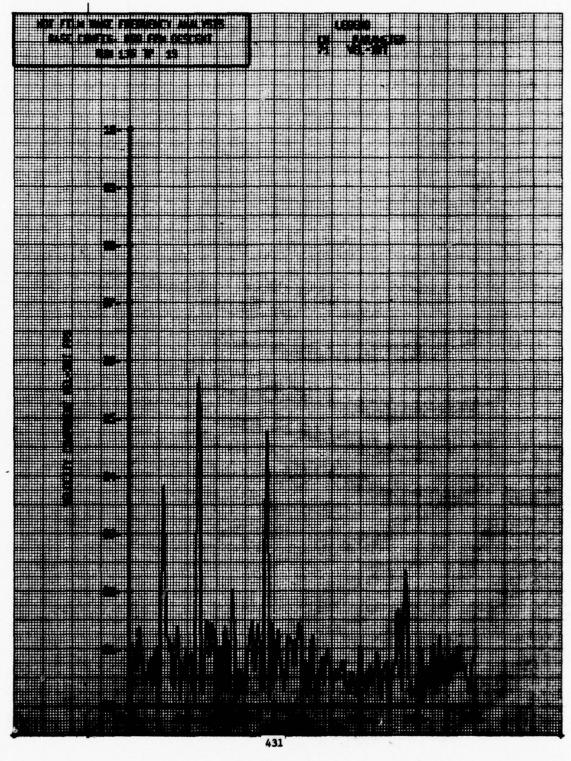
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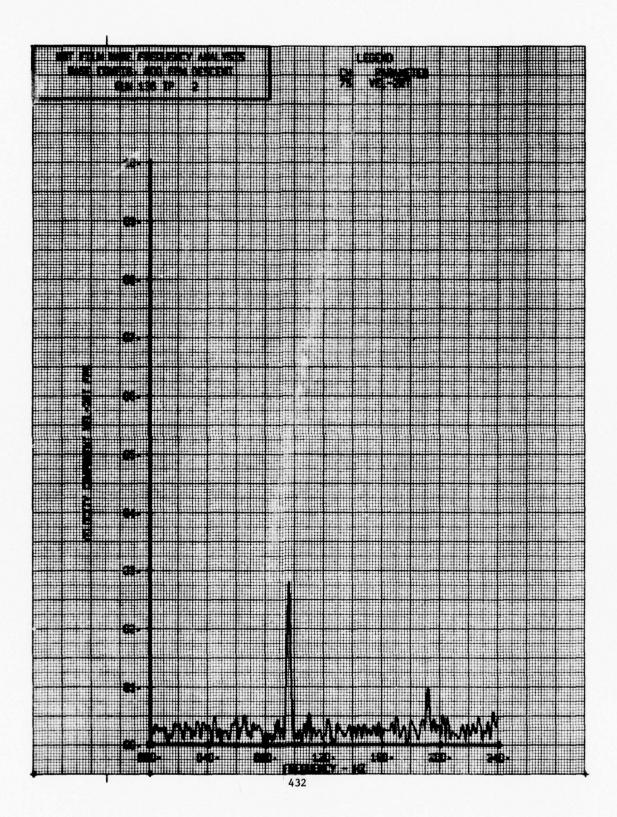


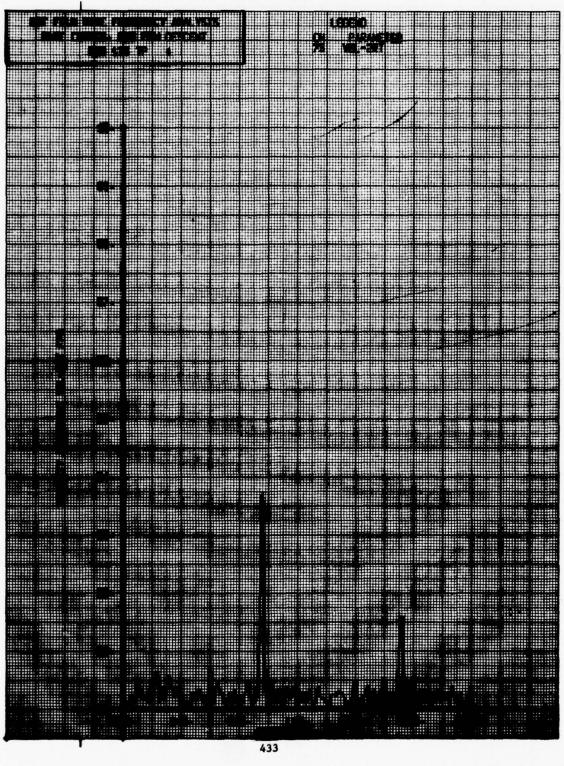
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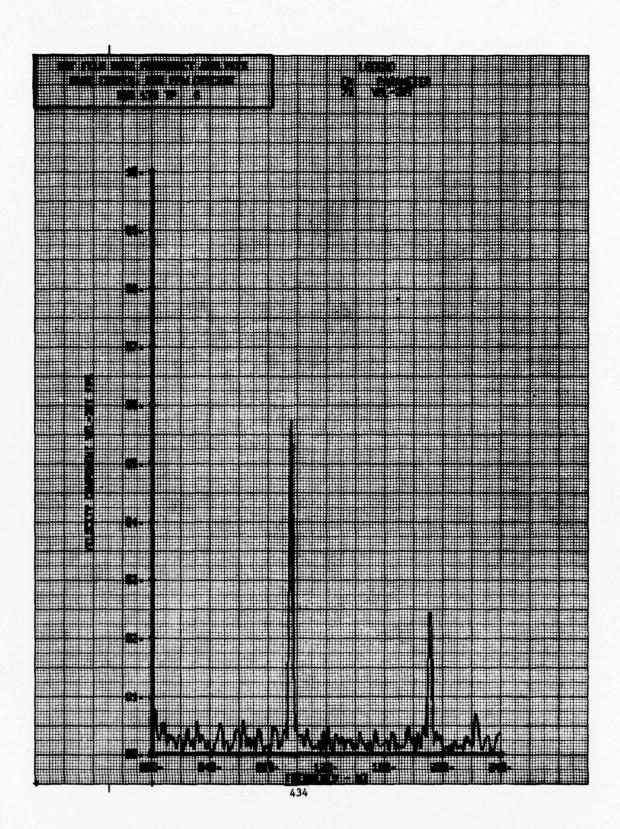
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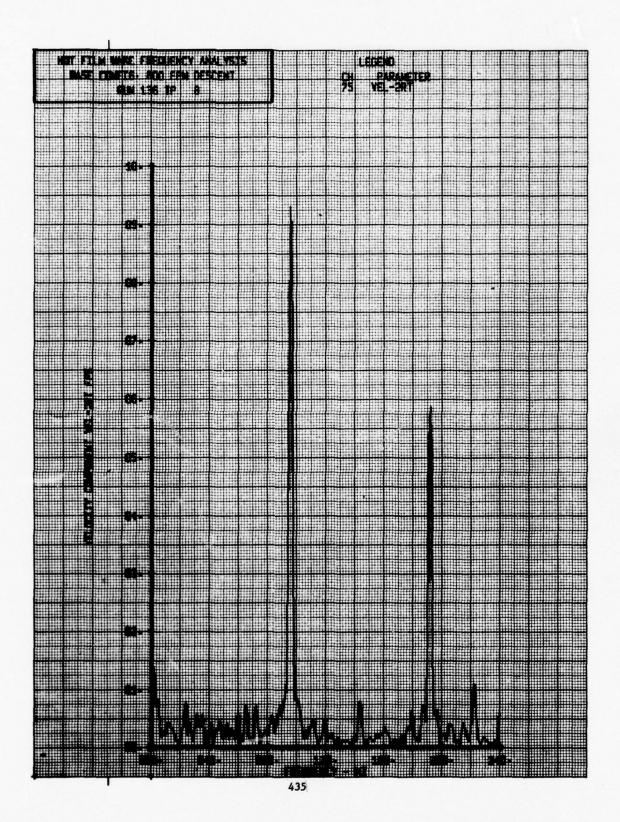




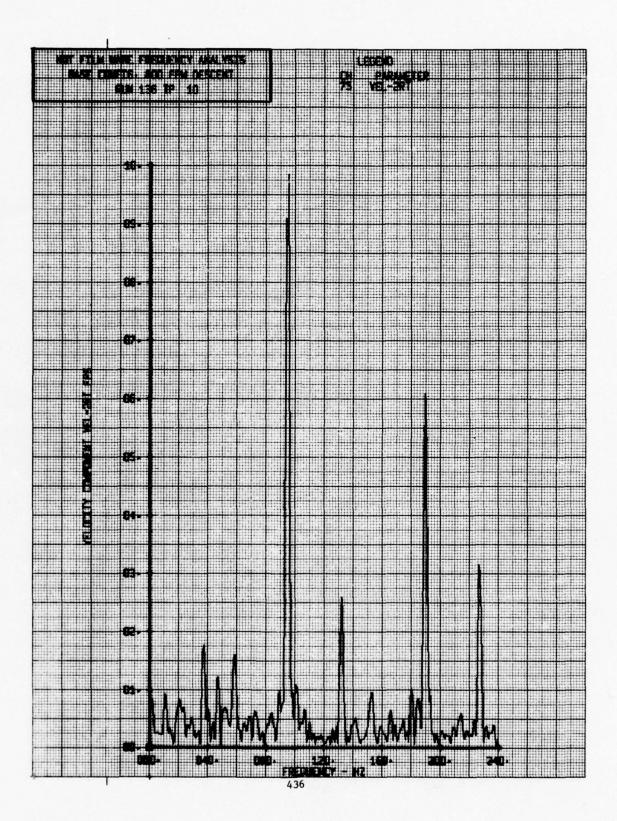
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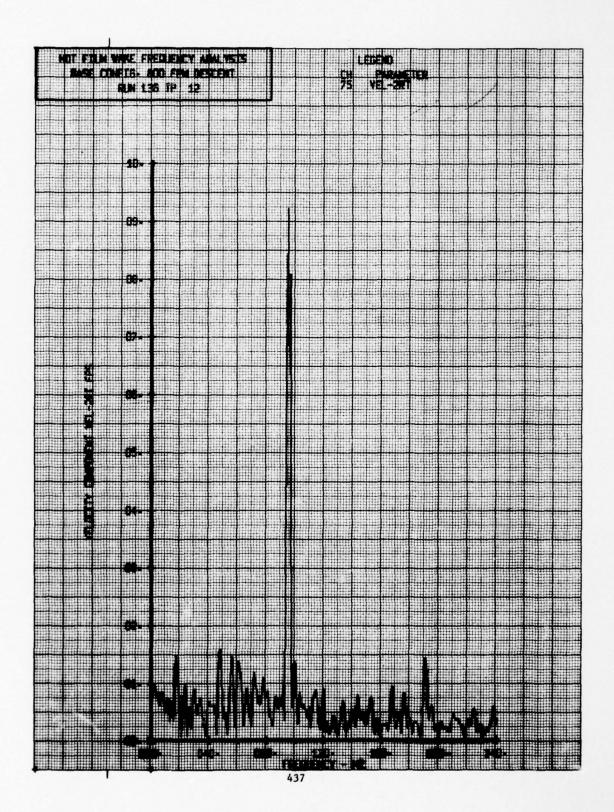
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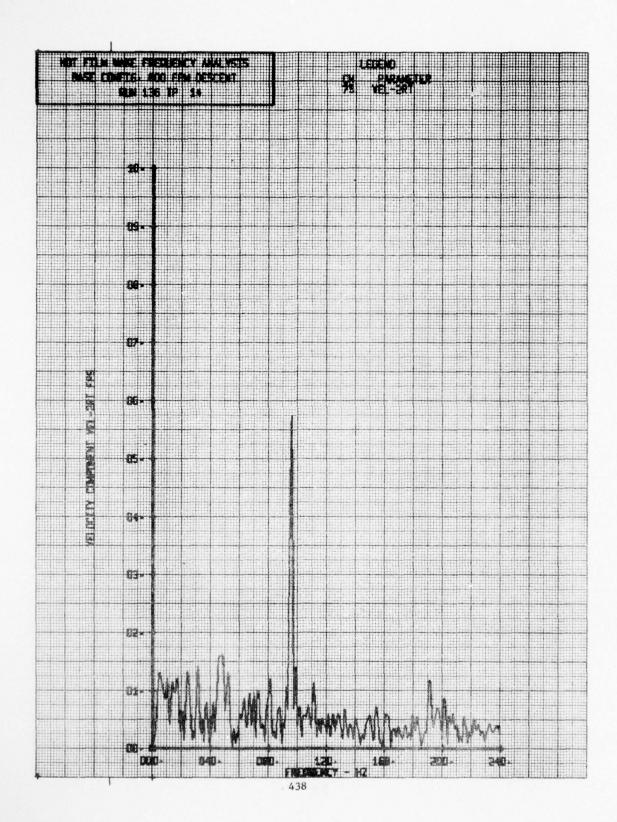
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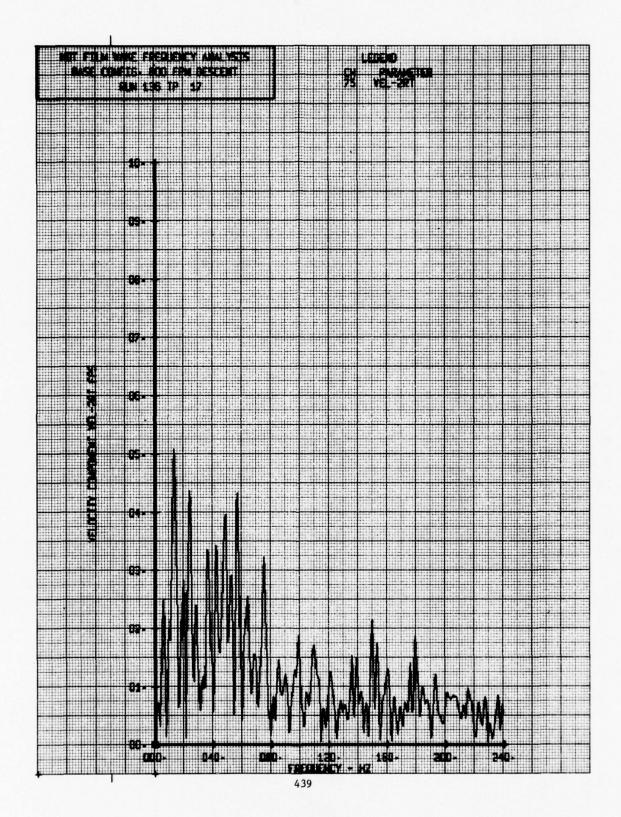


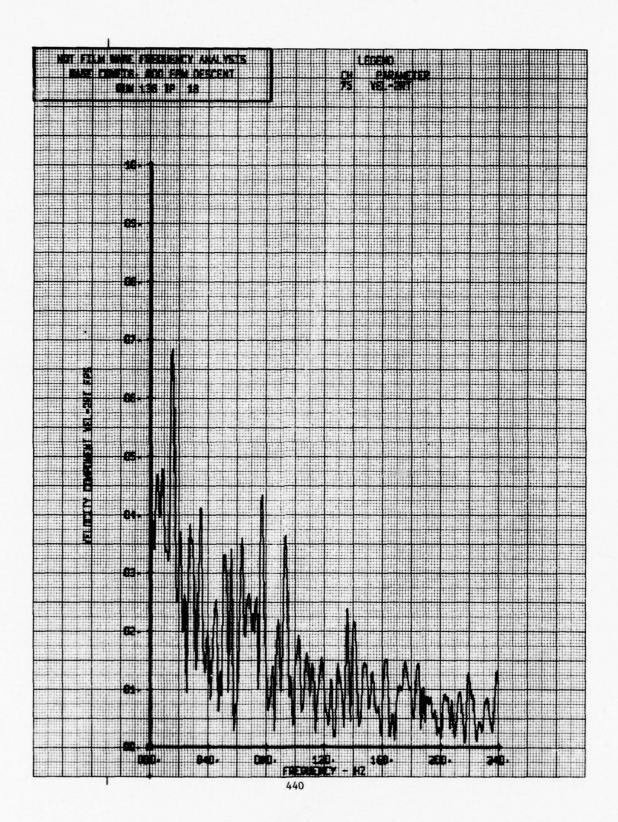
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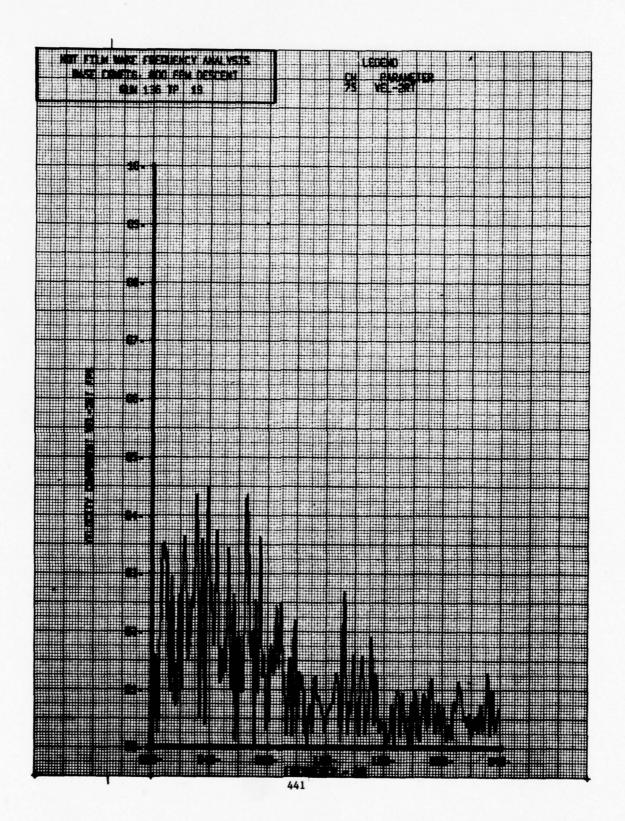
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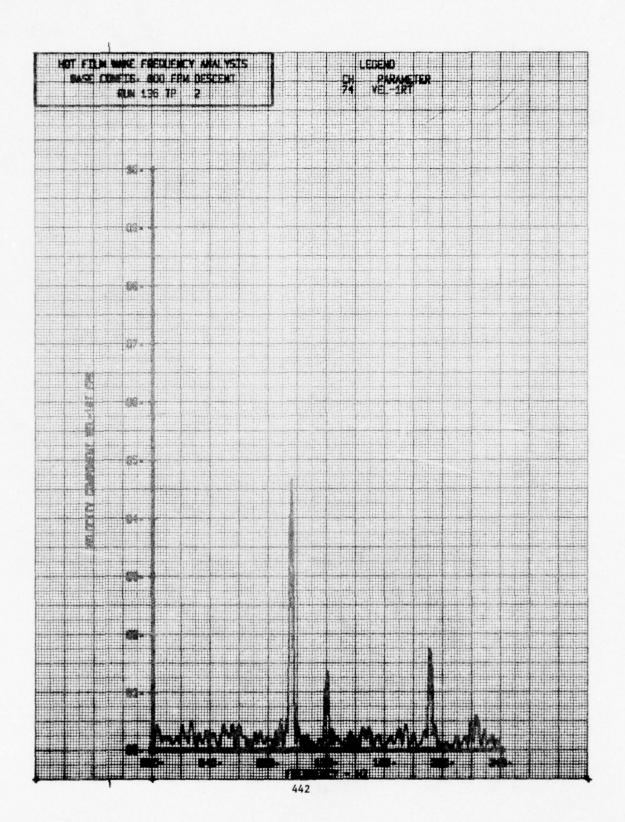


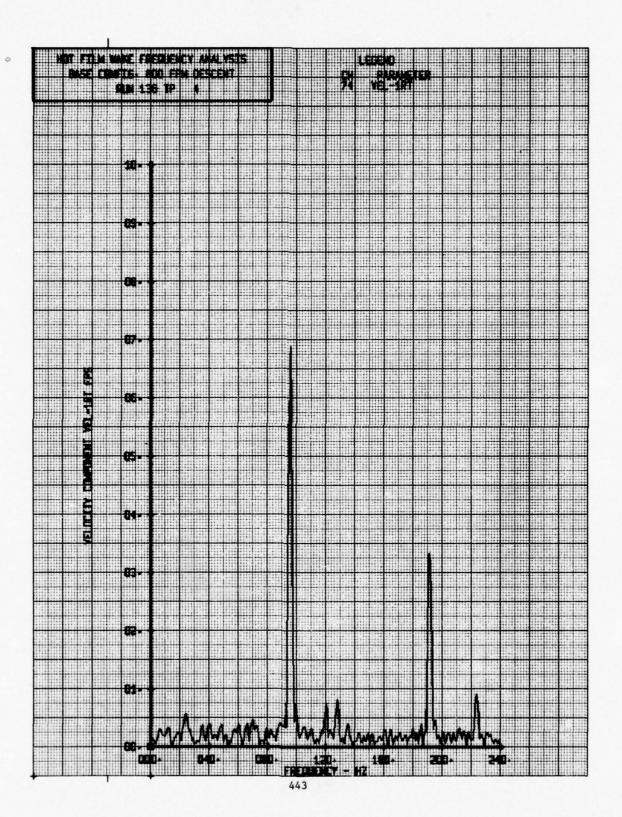


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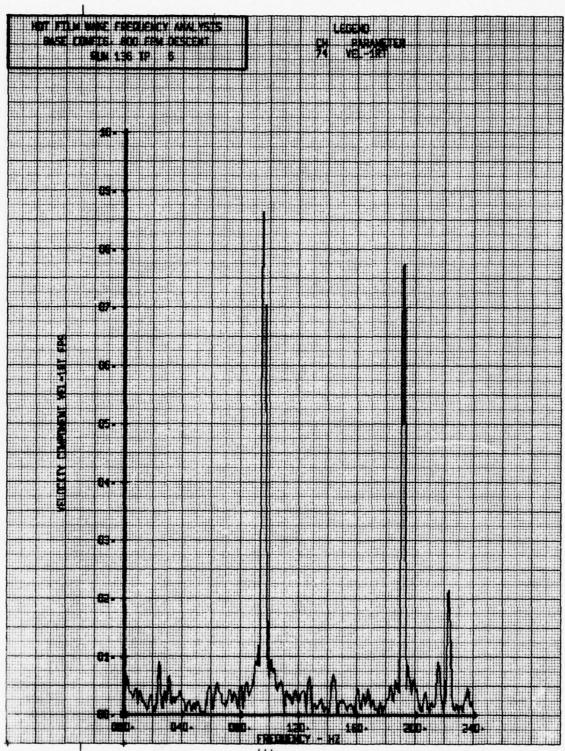


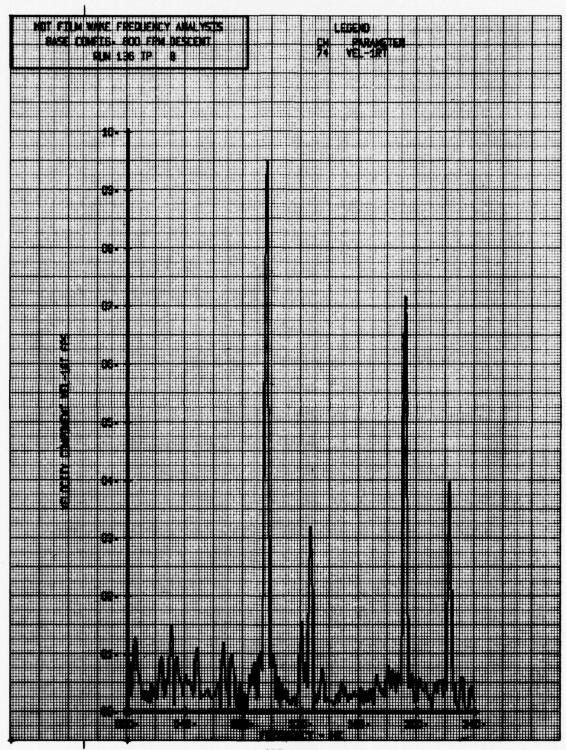
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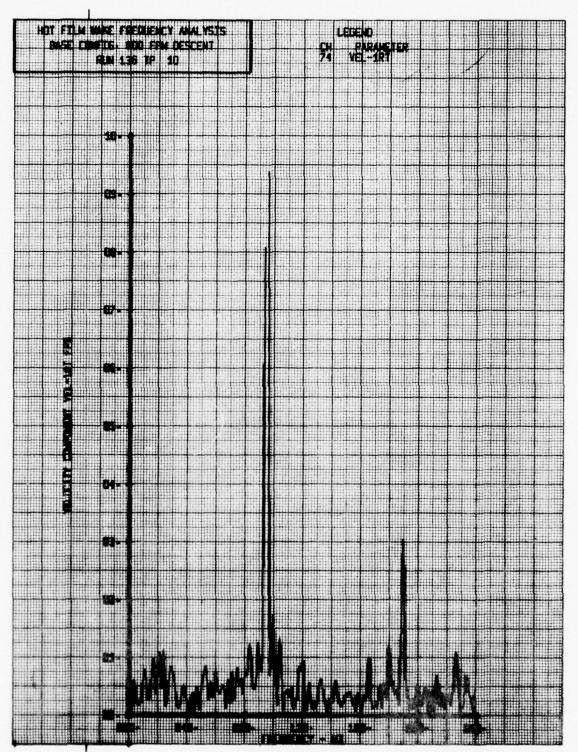


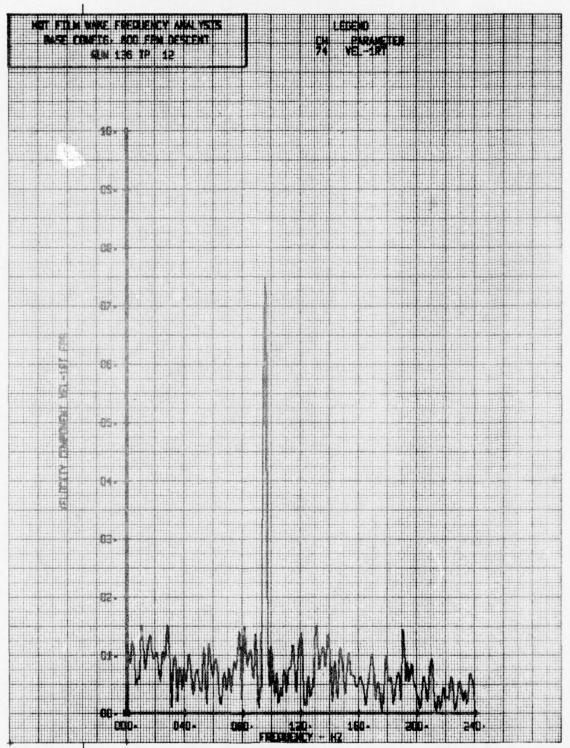


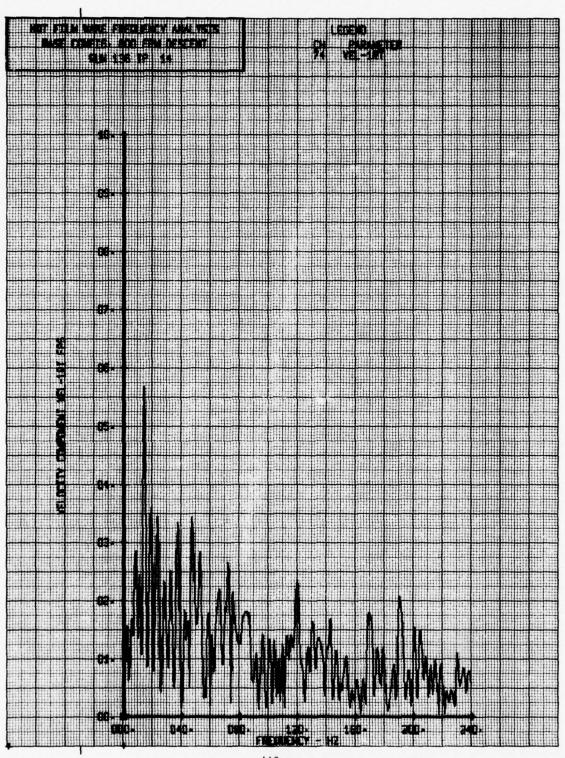
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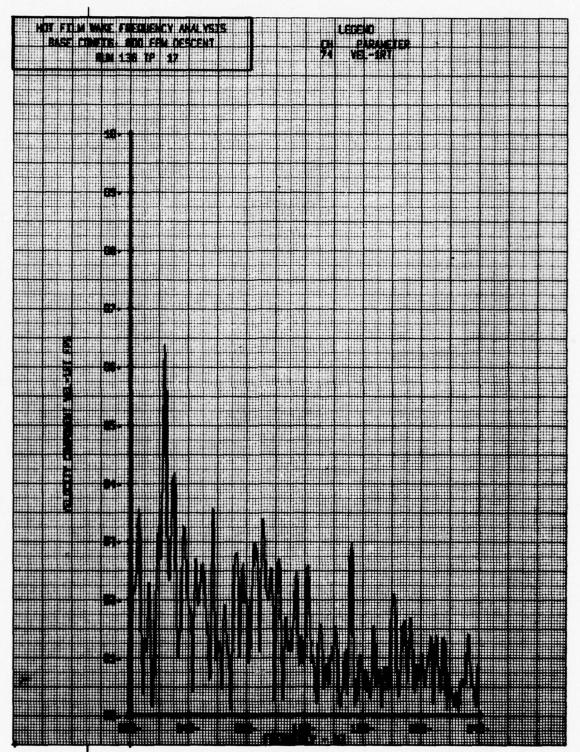


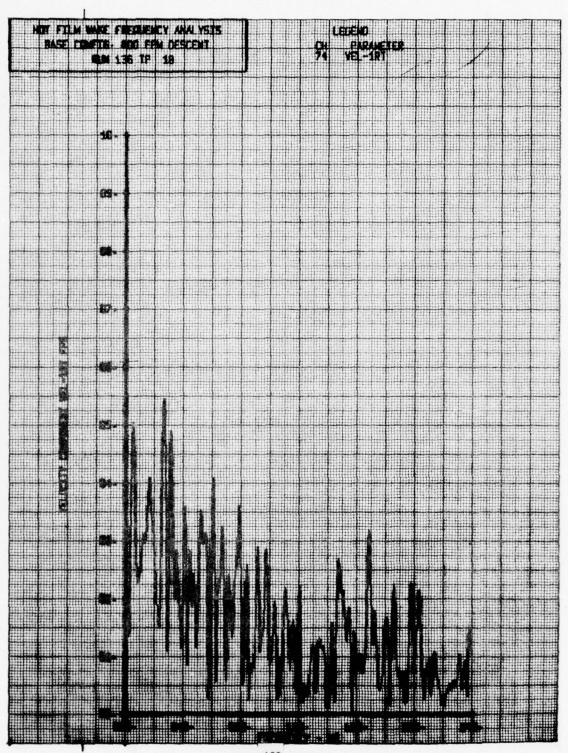




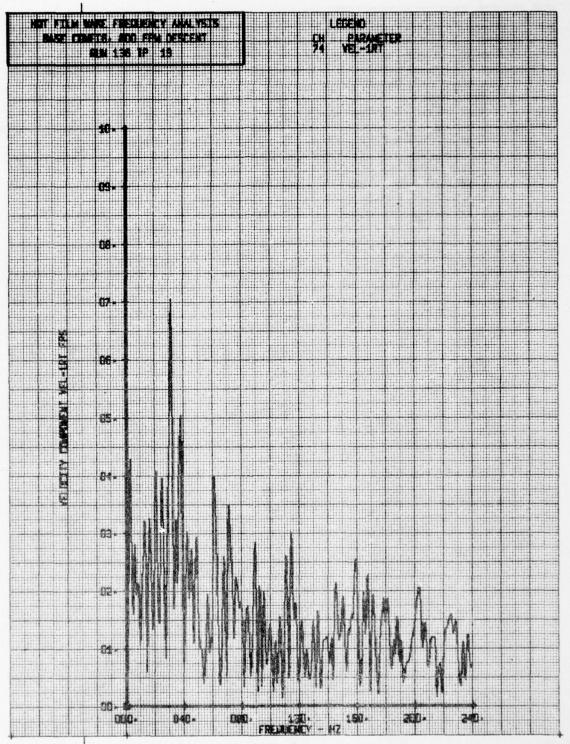


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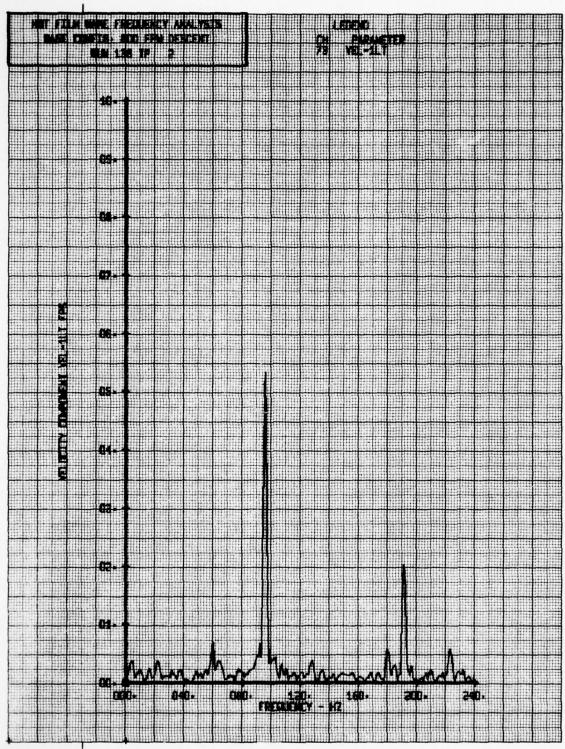




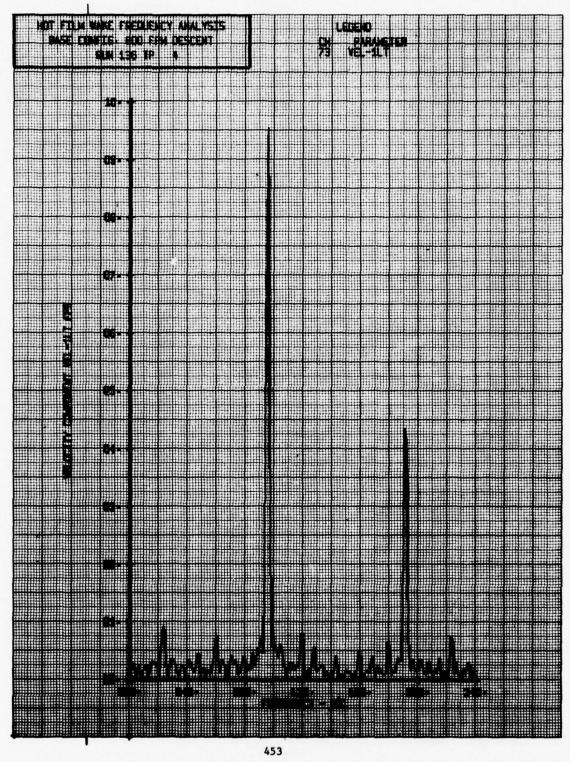
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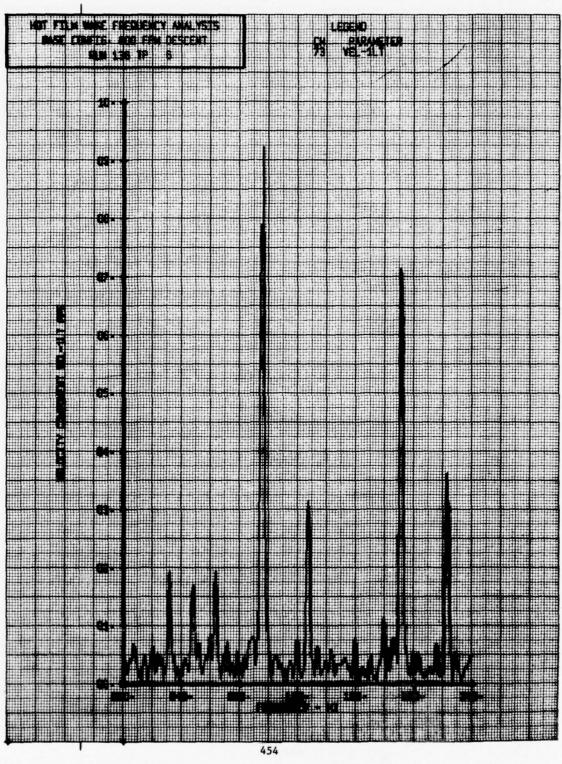
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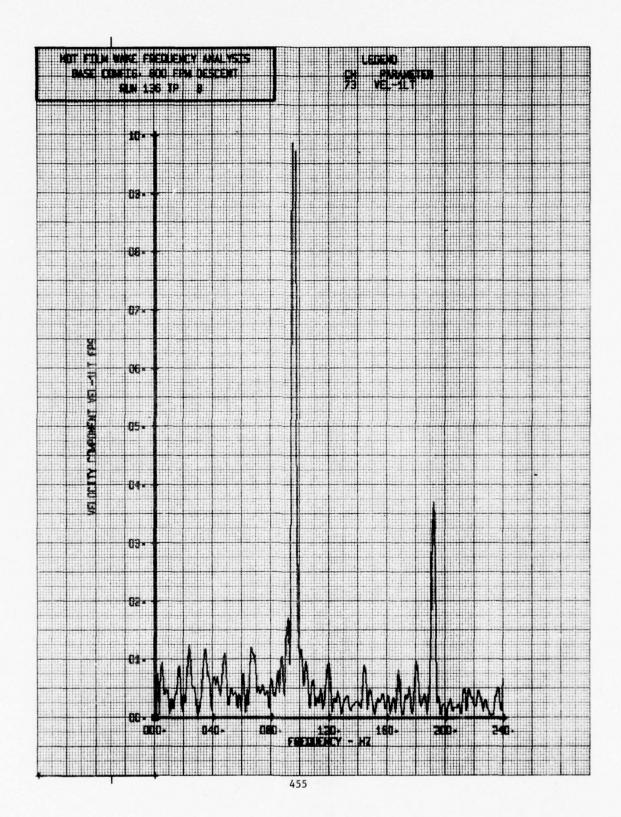
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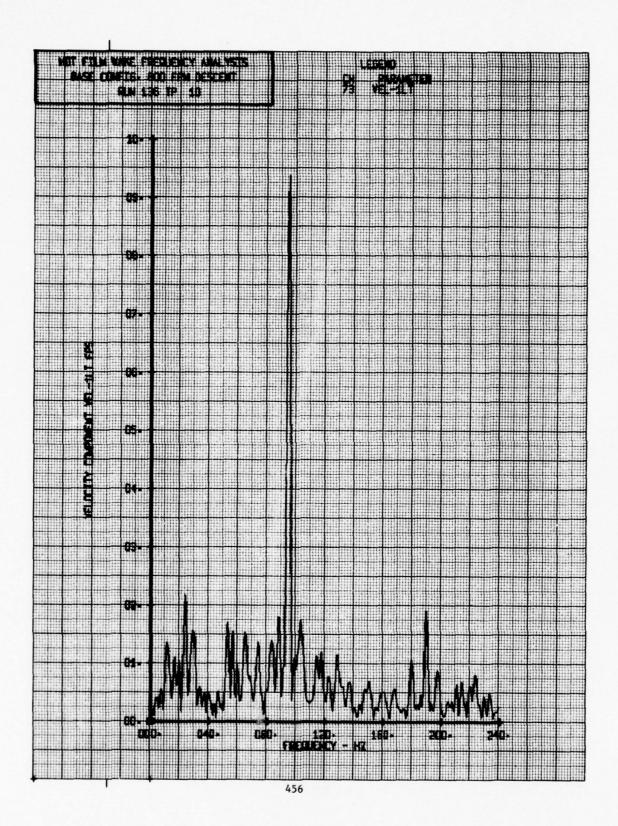
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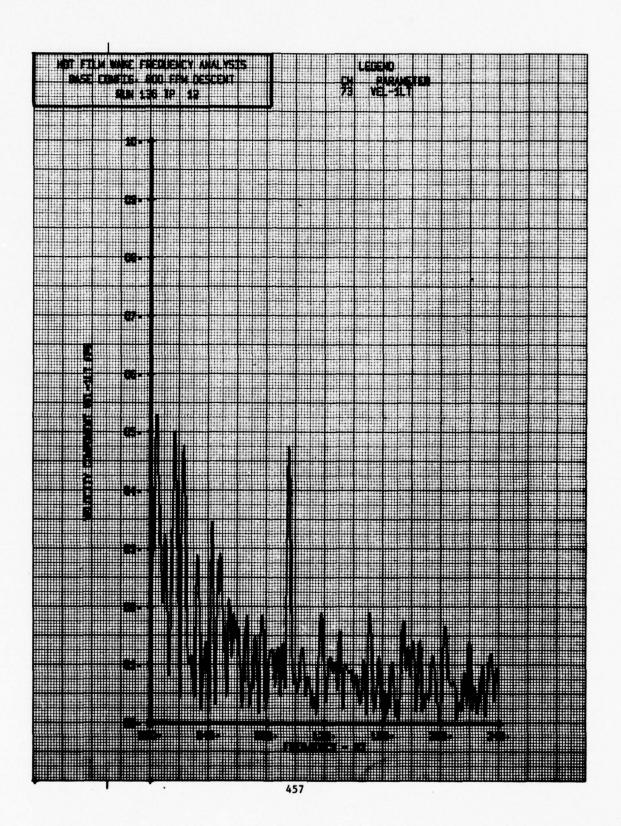
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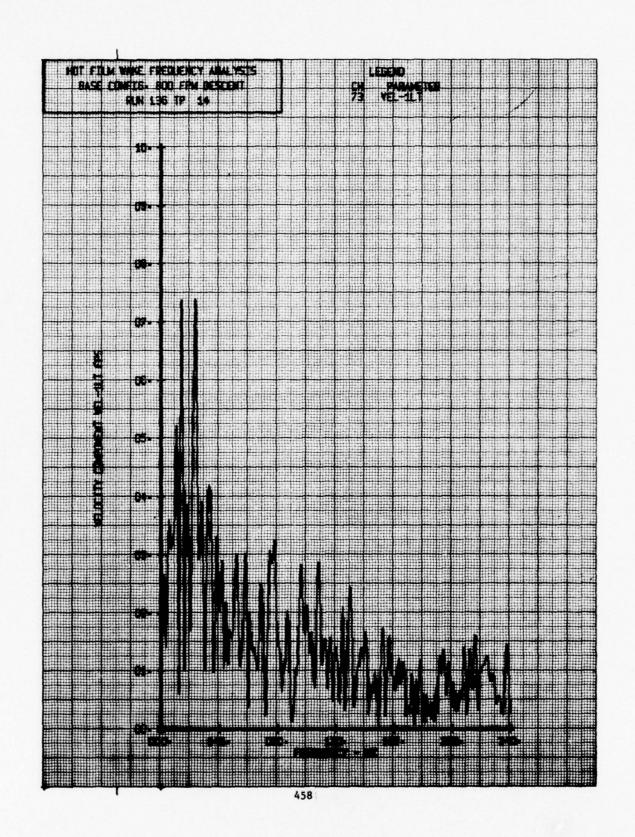


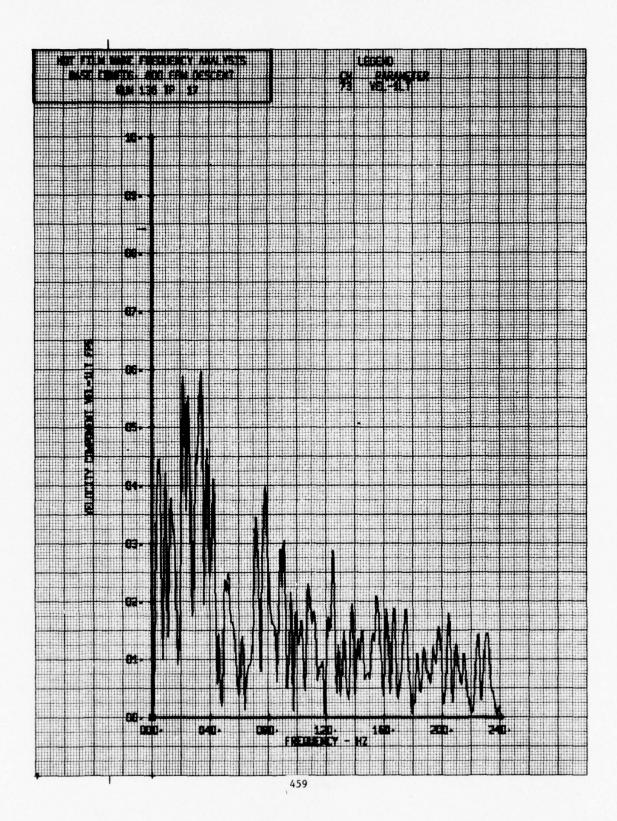
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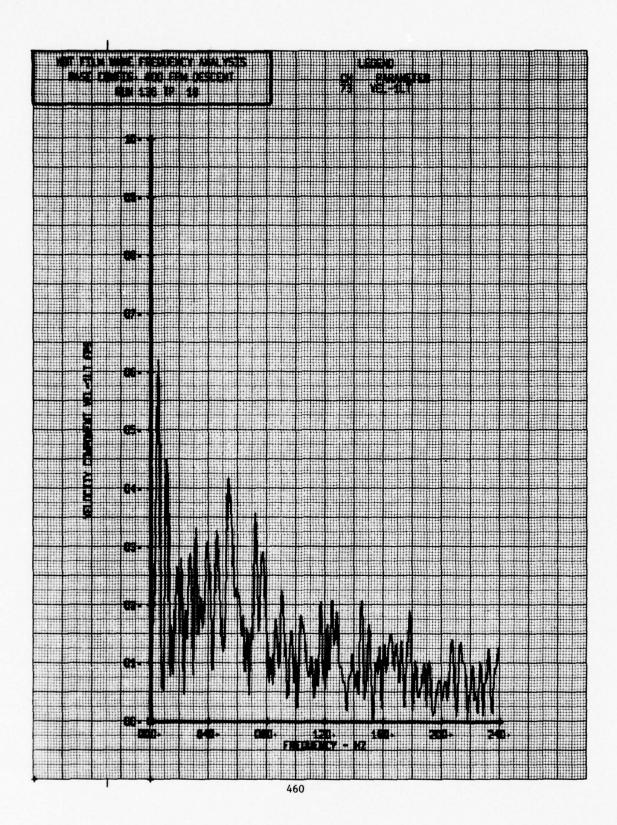
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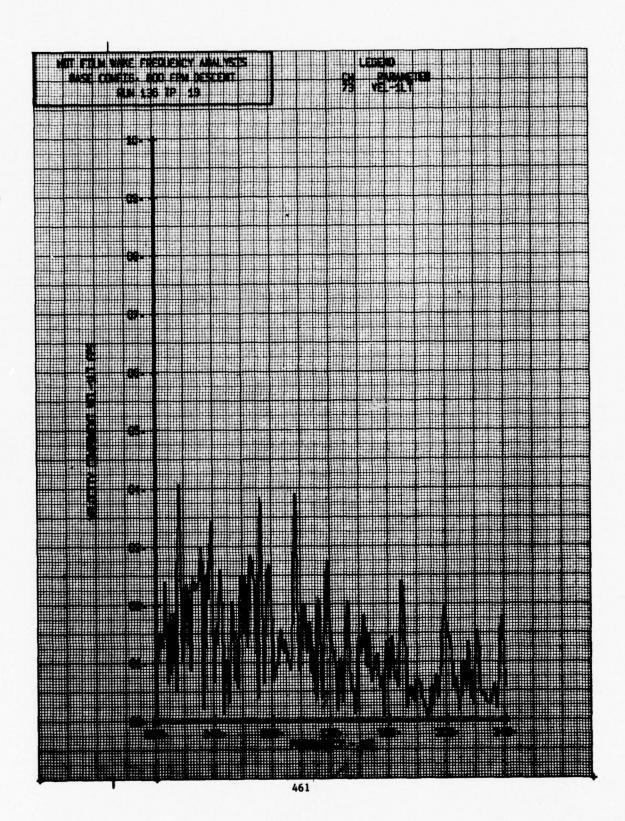




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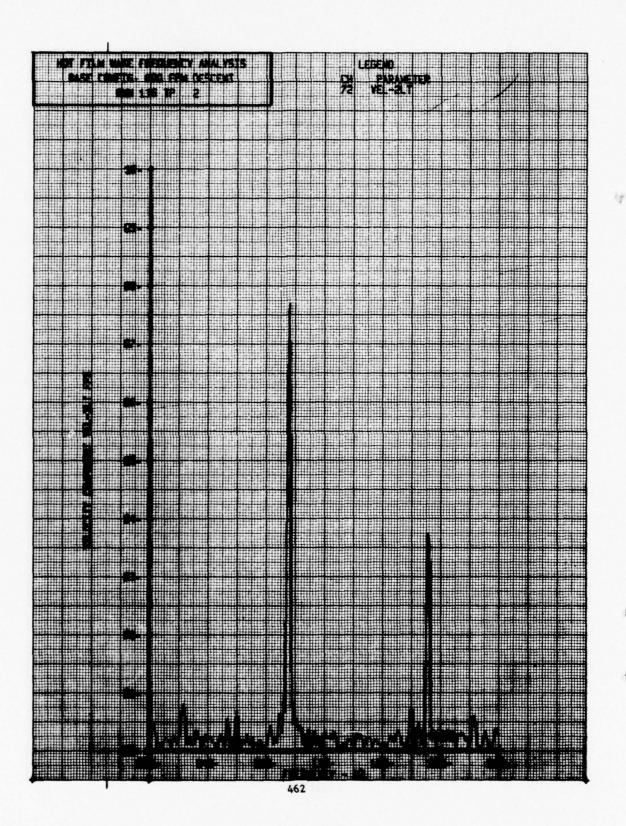


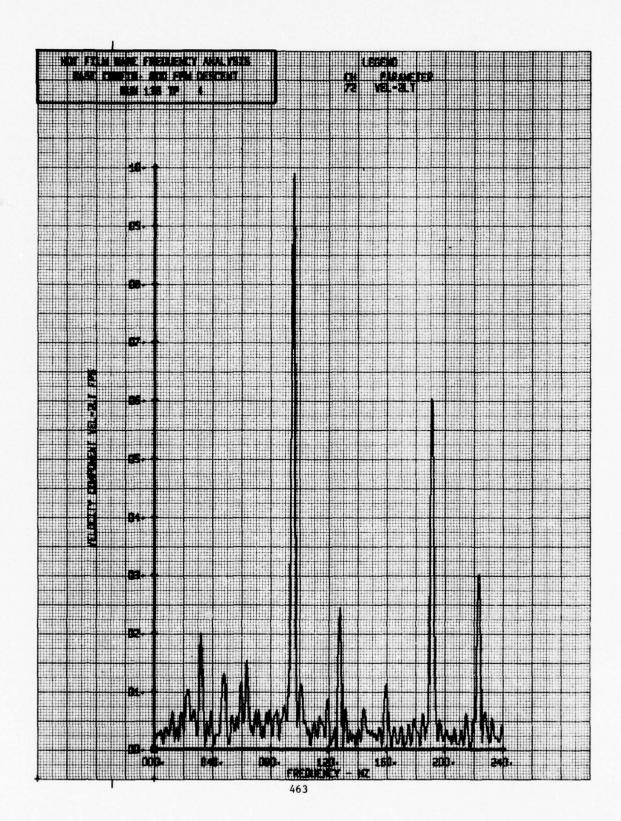
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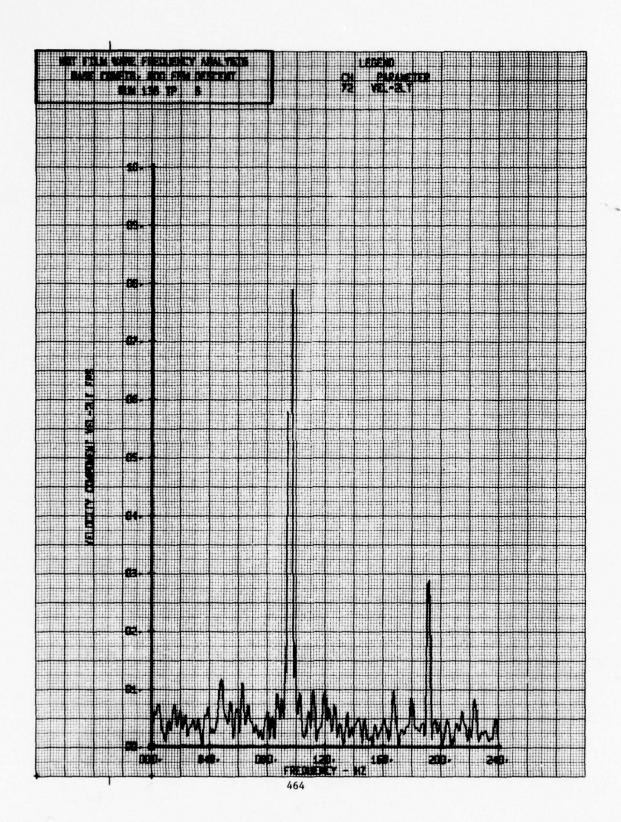
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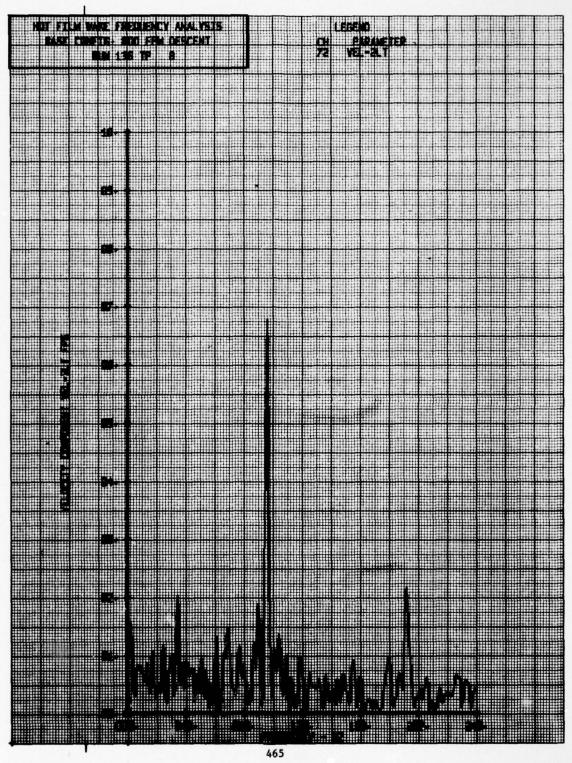




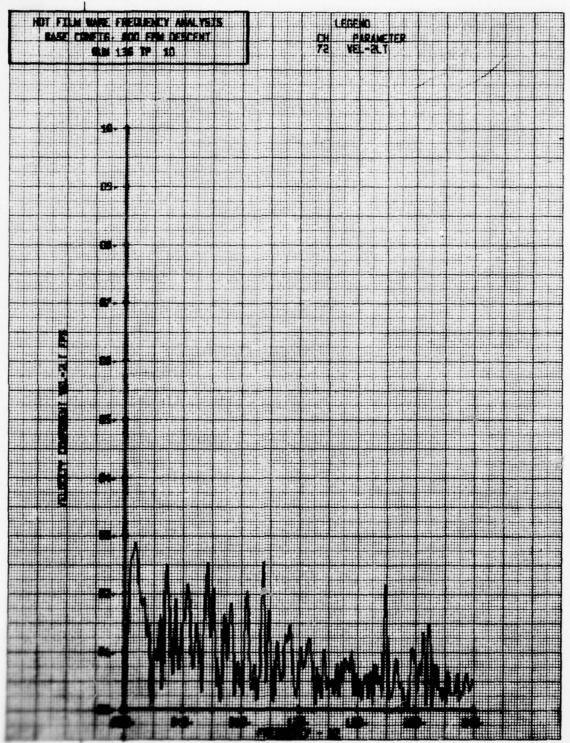
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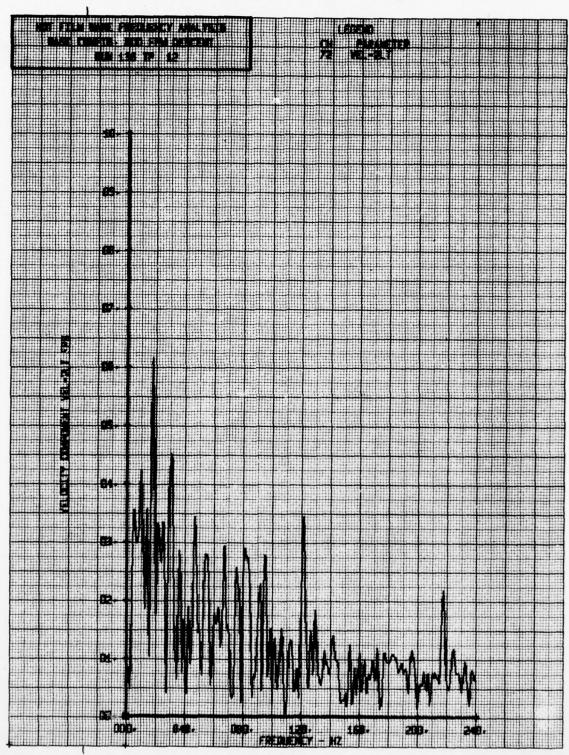
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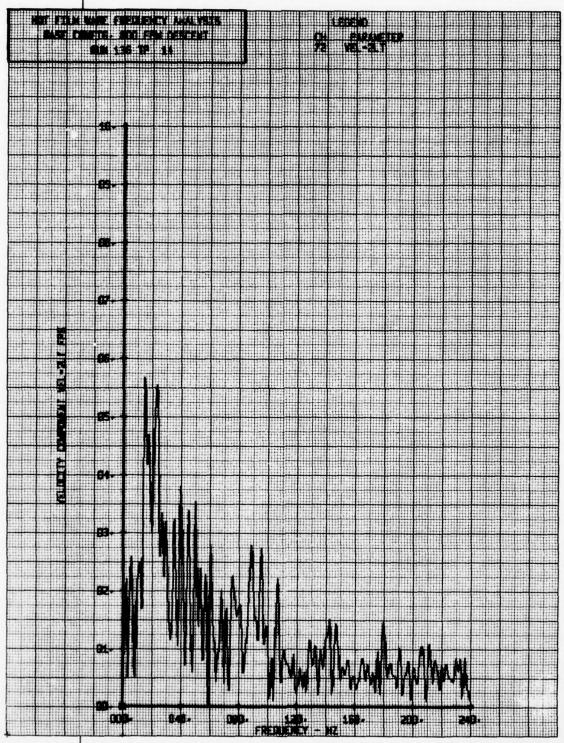
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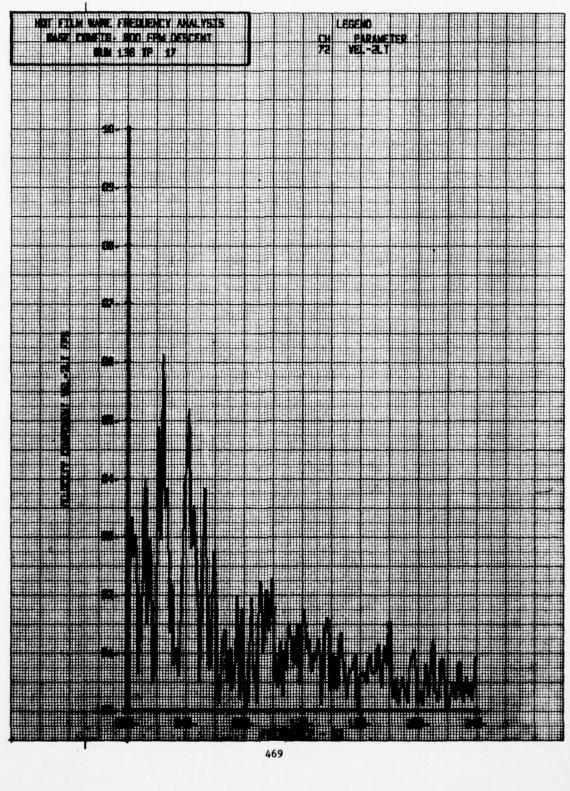


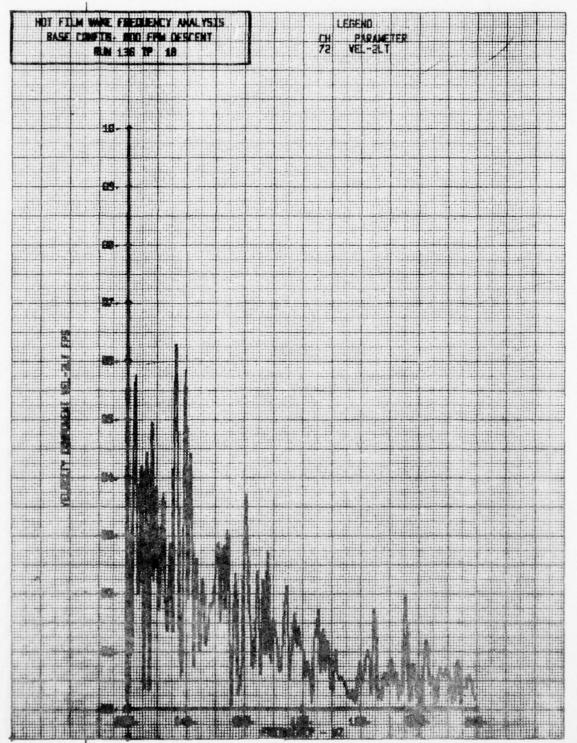
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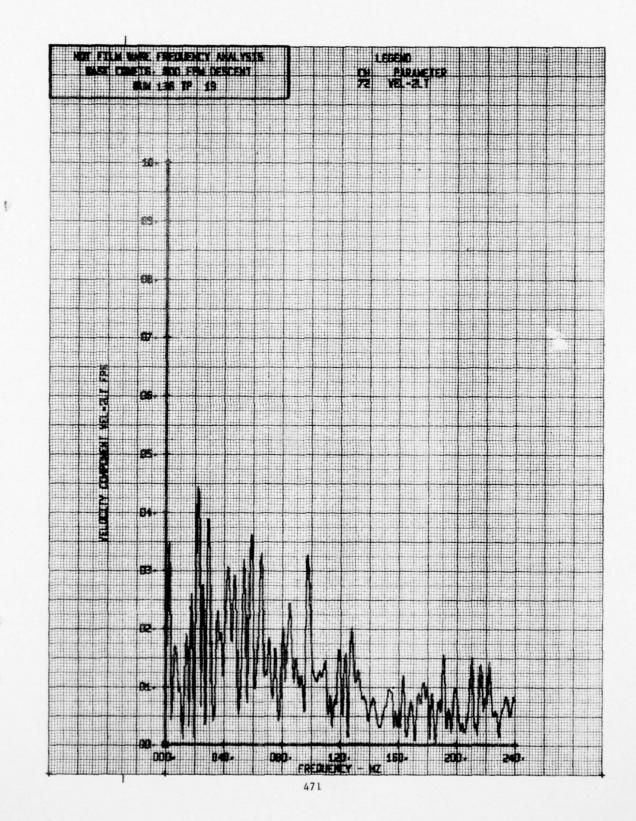


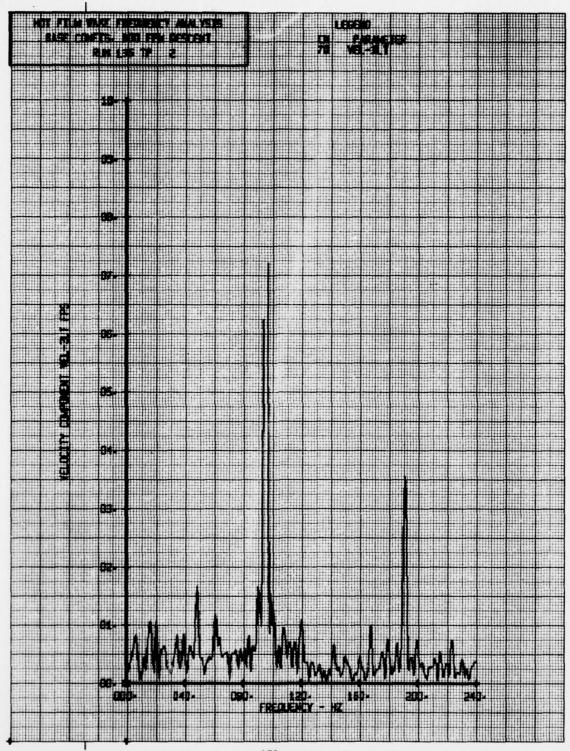
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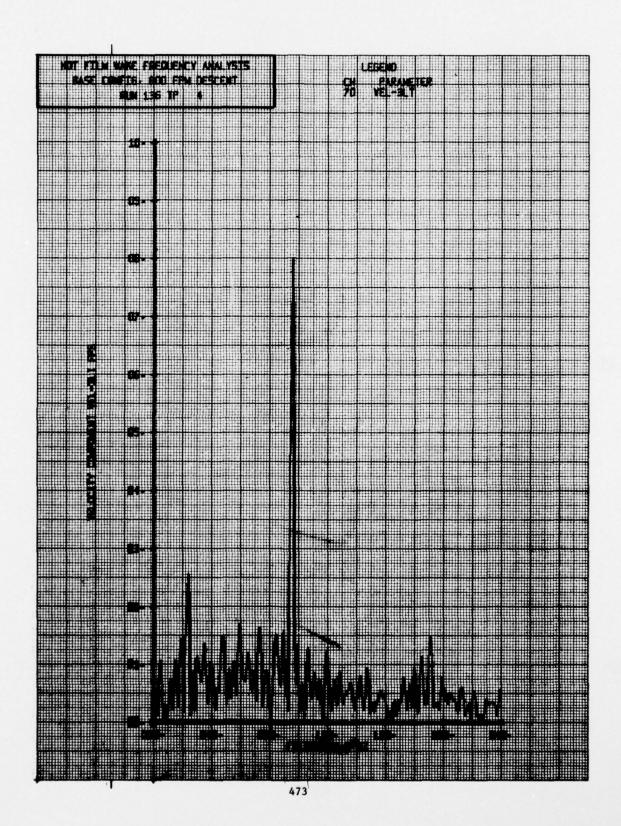




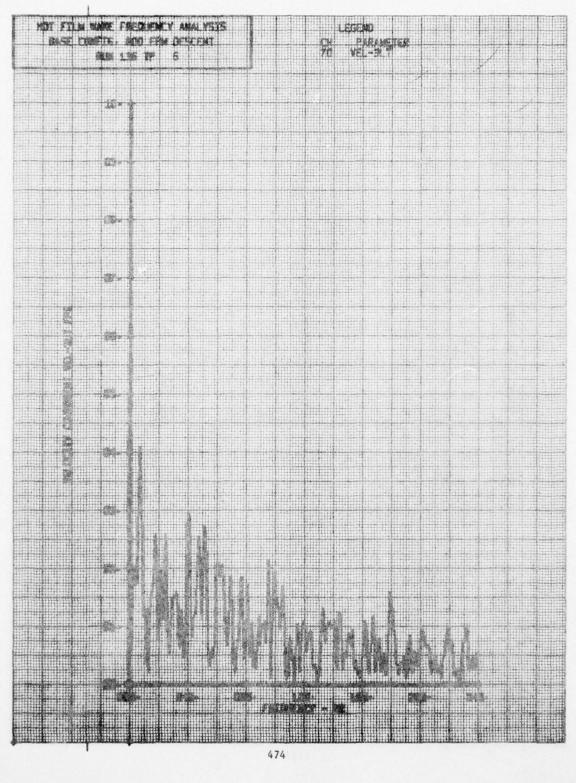


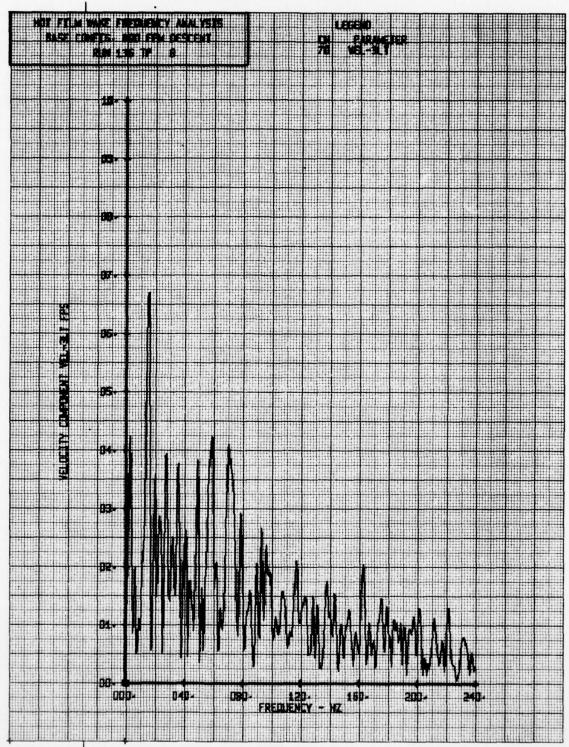
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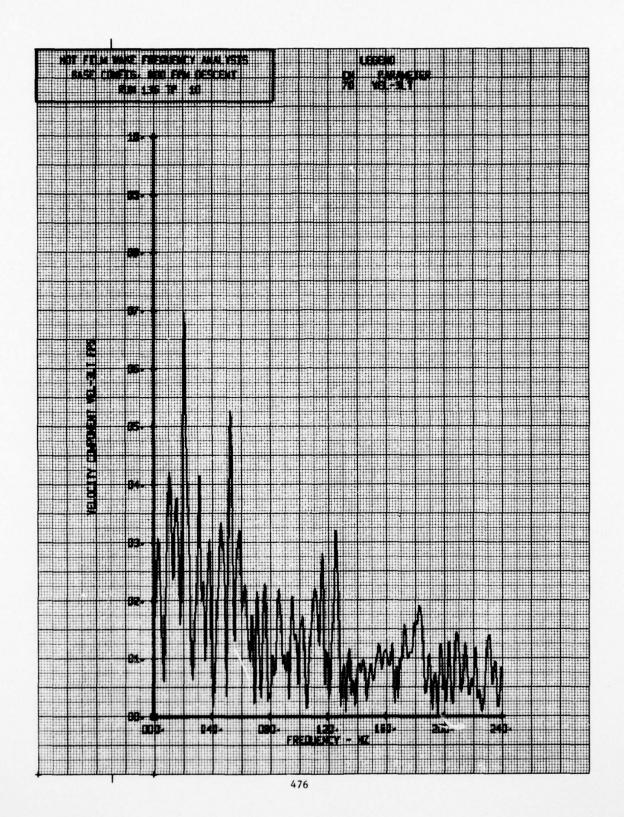
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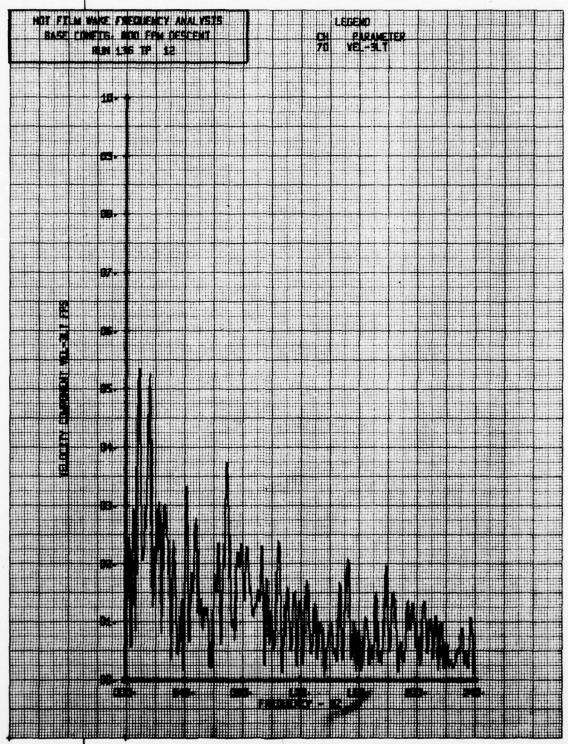


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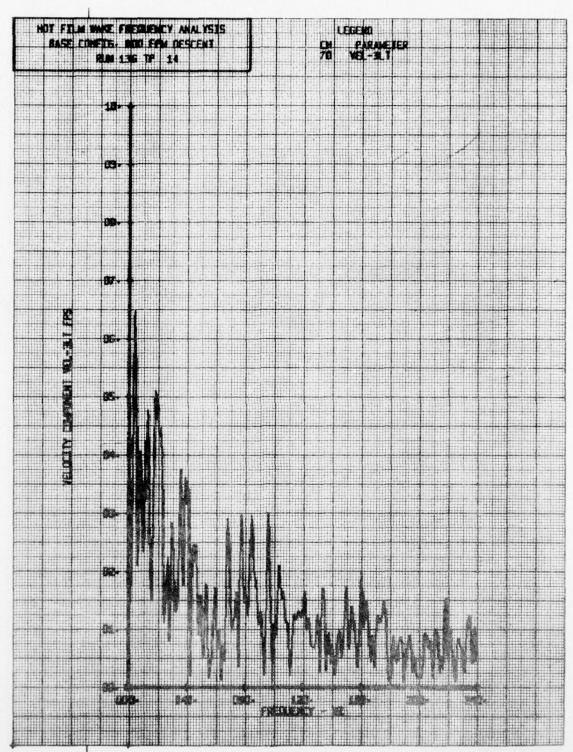
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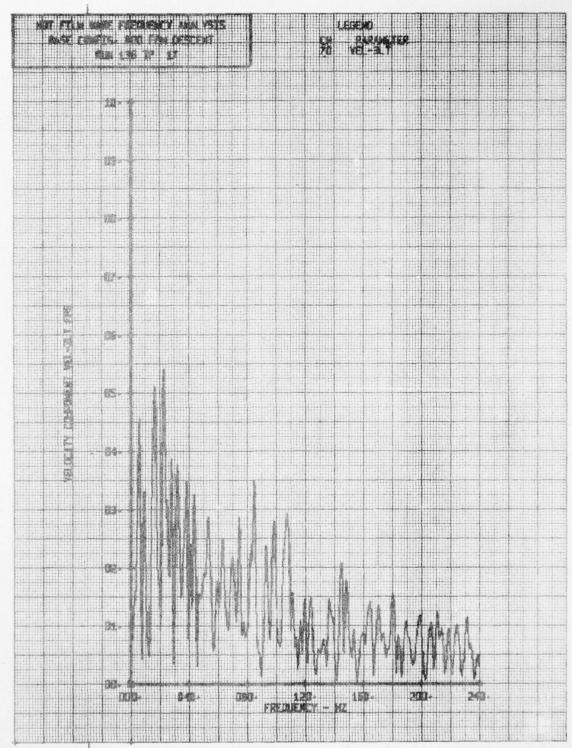
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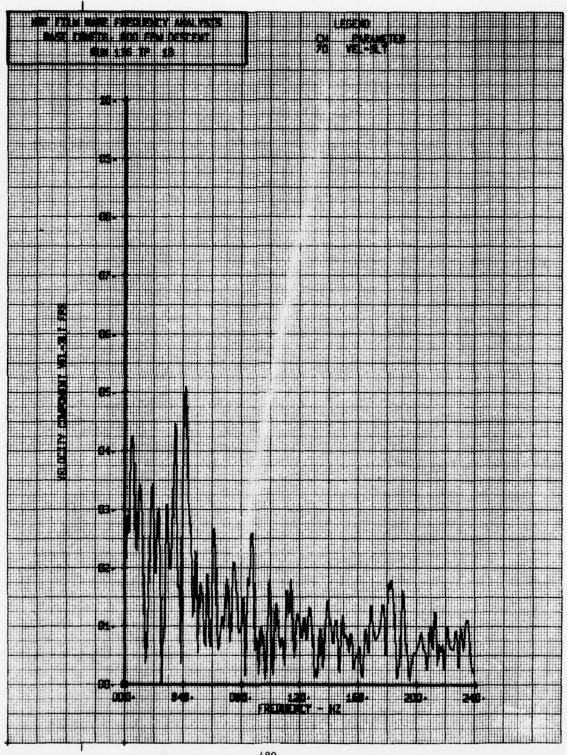
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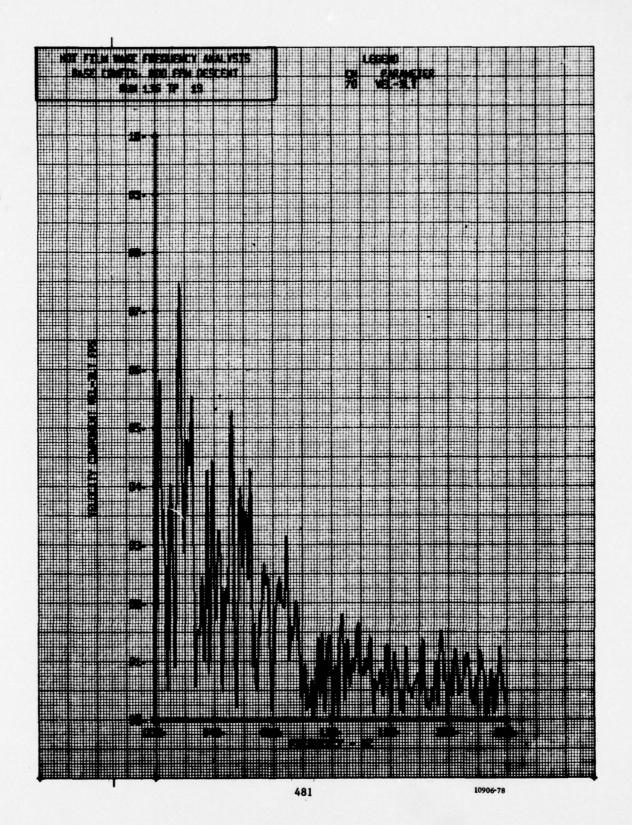


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